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of the
Astronomical Society of India.

EDITED BY C. T. LETTON, ESQ.
AND THE HON'BLE MR. W. A. LEE, F.R.M.S

VOL. V.

November 1914 to September 1915.

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The Journal of the
Astronomical Society of India.

VOL. V.] SESSION 1914-1915. [NOS. 1 & 2.

Report of the Meetings of the Society held on Tuesday, 3rd November 1914, on Tuesday, 24th November 1914, and on Tuesday, 22nd December 1914.

THE Annual General Meeting of the Society was held on Tuesday, the 3rd November 1914, in the Imperial Secretariat (Treasury Buildings), at 5-15 P.M. The Hon'ble Mr. W. A. Lee, F.R.M.S., the President of the Society, was in the chair.

The minutes of proceedings of the last meeting of the Society held on Tuesday, the 30th June 1914, were read and confirmed.

The Report of the Society for the session 1913-14 was adopted and the election of the following members as officers and members of Council for the session 1914-15 was announced :—

President	The Hon'ble Mr. W. A. Lee, F.R.M.S.
Vice-President	(1) H. H. the Maharaj Rana Bahadur Sir Bhawani Singh, K.C.S.I., F.R.A.S. (2) W. J. Simmons, Esq., B.A., F.R.A.S. (3) J. Evershed, Esq.,F.R.A.S. (4) Col. Lennox Conyngham, R.E., F.R.A.S.
Secretary (Scientific)	Dr. E. P. Harrison, Ph.D.
Do. (Business)	D. N. Dutt, Esq., M.A.
Treasurer	Rai Bahadur U. L. Banerjee, M.A.
Directors of Sections—	
Director of Classes	Revd. A. C. Ridsdale, M.A., F.R.A.S., F.R. Met. Soc., F. Ph. S., A.L.C.M.
Lunar Section	The Revd. J. Mitchell, M.A., F.R.A.S.
Variable Star Section	C. V. Raman, Esq., M.A.
Meteor Section	P. C. Bose, Esq.
Instrumental Director	S. Woodhouse, Esq.
Librarian	C. V. Raman, Esq., M.A.
Editor	C. T. Letton, Esq.
Other Members of Council	(1) Hari Das Das, Esq., B.E. (2) L. Demetrius, Esq. (3) J. C. Dutt, Esq., M.A., B.L. (4) S. C. Ghosh, Esq., M.A. (5) F. C. Gray, Esq. (6) J. C. Mitra, Esq., M.A., B.L. (7) Dr. D. N. Mullick, B.A., D.Sc. (8) The Revd. A. C. Ridsdale, M.A., F.R.A.S., F.R.Met. Soc., F.Ph.S., A.L.C.M. (9) Captain A. M. Urquhart, R.A. (10) Mrs. Percy Brown.

The President then delivered his address.

The monthly Meetings held on 24th November and 22nd December 1914 were presided over by the President, the Hon'ble Mr. W. A. Lee. The papers read at these Meetings are published in this issue.

The Report of the Astronomical Society of India for the year ending 30th September 1914.

The Council beg to submit the following report on the progress and operations of the Astronomical Society of India for the session 1913-14 which ended on 30th September 1914.

2. *Members.*—The Society has completed the fourth year of its existence. It entered into its fourth session with 210 members and closed it with 162. There were 9 new admissions and 14 resignations, and 43 were struck off the rolls under Bye-law No. 27 for default in payment of subscriptions.

3. *Meetings.*—The Council held 8 ordinary and 3 special meetings for conducting the business of the Society, and a Sub-Committee of the Council met three times to arrange the details of an At Home given during the year to the members and a number of guests.

The Annual General Meeting of the Society for electing the office-bearers for the session 1913-14 was held on 31st October 1913. There were also 8 ordinary monthly meetings of the members at which papers were read and discussions held. A list of the papers read with the names of their authors is given at the end of this report.

4. *Public lectures.*—For the benefit of the general public three public lectures in popular language were delivered free at the Town Hall, Calcutta, on the 8th January 1914, the 12th February 1914, and the 20th March 1914. The lectures were on the following subjects :—

(1) The Great Star Map

(2) Jupiter. The Giant Planet

(3) Astronomy—Ancient and Modern,

and were delivered by Mr. A. B. Chatwood, B.A., F.R.A.S., Director, Nizamiah Observatory, Hyderabad, by the Revd.

J. Mitchell, M.A., F.R.A.S., Principal, Wesleyan College Bankura, and by Dr. D. N. Mullick, M.A., D.Sc., F.R.S.E. Professor, Presidency College, Calcutta, respectively. The lectures were well attended and were presided over, the first by the Hon'ble Mr. P. C. Lyon, C.S.I., I.C.S., the second by the Hon'ble. Mr. Justice C. W. Chitty and the third by the Hon'ble Justice Sir H. L. Stephen, C.V.O. The best thanks of the Society are due to the Chairman of the Corporation of Calcutta for having lent the Town Hall free of charge, except for cost of lights and fans, for the purposes of these lectures, to the authors of the lectures and to the gentlemen who presided over them.

5. *At Home.*—On the 4th February 1914 the President and Council of the Society were At Home to the members and a number of guests on the grounds of No. 28 Chowringhee kindly placed at their disposal by Mrs. Percy Brown. The invitations were largely responded to and a very enjoyable evening was spent. Great interest was taken by the guests in the astronomical instruments that were arranged on different parts of the grounds.

6. *Journal of the Society.*—The journal of the Society was issued monthly up to April 1914. It was then decided to make one issue for May, June and July. In all, therefore, there were six monthly issues and one quarterly issue during the session. The Memoranda for Observers published in these issues were prepared by Mr. Henry Hart of Mangalore, to whom the Society is indebted for his labour of love.

7. *Recognition of the Society.*—The following Societies and Observatories regularly exchanged their publications with those of the Society :—

1. Royal Astronomical Society of London.
2. British Astronomical Society of London.
3. Royal Astronomical Society of Canada.
4. South African Association for the Cultivation of Science.
5. Astronomical Society of Barcelona.
6. Royal Observatory of Scotland.
7. Vatican Observatory.
8. Astronomer Royal, Greenwich.
9. Royal Observatory of Belgium.
10. Director of Indian Observatories, Alipore.
11. Director of Kodaikanal Observatory.

12. Oxford University Observatory.
13. Radcliffe Observatory.
14. Astronomical Society of Leeds.
15. Paris Observatory.
16. Astronomical Society of Wales.
17. Nizamiah Observatory, Hyderabad.
18. Saraswat Chatuspathi, Calcutta.

The acknowledgments of the Society are due to these Societies and Observatories for this exchange.

The Journal of the Society continues to be subscribed by the following educational institutions :—

1. The Presidency College, Calcutta.
2. The Sanskrit College, Calcutta.
3. The Hooghly College, Chinsurah.
4. The Krishnanagar College.
5. The Patna College.
6. The Muir Central College, Allahabad.
7. The Elphinstone College, Bombay.

The Journal is also supplied free to the Imperial Library, Calcutta.

8. *Government grant.*—The Council have much pleasure to announce that in July 1914 His Excellency the Governor of Bengal favoured the Society with a donation of Rs. 500 in aid of its funds and that the question of giving the Society an annual Government grant is under the consideration of the Government of Bengal. The receipt of the donation has been acknowledged with grateful thanks.

9. *Library.*—Some valuable books and periodicals were kindly presented to the Library by the President of the Society during the course of the year, and the number of books other than journals has now risen to 222. All possible facilities were given to the members for taking out books and other papers for study. The Library is now kept open on Mondays every week from 5 to 7 P.M.

10. *Quarters.*—The business of the Society continues with the permission of the Comptroller General to be conducted in two rooms of the Imperial Secretariat (Treasury) Buildings which are used during office hours for office purposes and the Library continues to be housed in a room in the same

buildings placed at the disposal of the Society by the Comptroller General. The gratitude of the Society is due to the Comptroller General for his kindness.

11. *Accounts.*—The accounts of the Society for the year under report are shown in the accompanying statements.

List of Papers read at the Ordinary Monthly Meetings of the Society.

SESSION 1913-14.

1.	The Shifting Ecliptic ...	By Mr. Henry Hart.
2.	The forces which go to determine the motions of the Moon in space	,, the Revd. A. C. Ridsdale.
3.	The composition of the Tonk Meteorite	,, Dr. W. A. K. Christie.
4.	The movements of the Planets in 1914.	,, Mr. Henry Hart.
5.	Notes on the Moon ...	,, Captain A. M. Urquhart.
6.	Observations of the Gegenschien.	,, M. C. V. Raman.
7.	An approximate method of computing precession in certain cases	,, Mr. A. B. Chatwood.
8.	Saturn in a small telescope ...	,, Mr. C. V. Raman.
9.	Some mathematical calculations of the dimensions, weight, etc., of Earth, Moon and Sun	,, The Revd. A. C. Ridsdale.
10.	Jupiter	,, The Revd. J. Mitchell.
11.	Mira Ceti	,, Miss M. C. Feline.
12.	Orbits of Celestial bodies as elliptical, parabolic and hyperbolic plane curves ...	,, The Revd. A. C. Ridsdale.

Revenue Account, Session 1913-14.

General Revenue Account for Session 1913-14.

EXPENDITURE.	Rs. A. P.
To Establishment	342 5 0
,, Postage and Telegram charges	90 7 0
,, Office Expenses and Miscellaneous... ...	95 5 0
,, Discount for cashing cheques	0 8 0
,, Typing charges	8 0 0
,, Printing charges :— Cost of Printing Journals	496 0 0
,, Cost of miscellaneous printing	75 9 0
,, Depreciation in the stock of Library Books ...	24 1 4
,, Depreciation in furniture	12 11 9
,, Depreciation in telescope	7 2 0
	1,152 1 1

RECEIPTS.	Rs. A. P.	Rs. A. P.	
By Subscription—			
210 members on 1-10-13 @ Rs. 8		1,680 0 0	
Add—New members—			
8 @ Rs. 8		64 0 0	
1 @ Rs. 4		4 0 0	
		1,748 0 0	
Deduct—			
43 members struck off @ Rs. 8 ...	344 0 0		
12 resigned @ Rs. 8	96 0 0		
2 dead @ Rs. 4 ...	8 0 0		
		448 0 0	
		1,300 0 0	
Amount realised for Session 1913-14—			
107 @ Rs. 8 ...=	856 0 0		
10 @ Rs. 4 ...=	40 0 0		
		896 0 0	
Deduct—Amount realised in 1912-13		32 0 0	864 0 0
Amount in arrears—			
47 @ Rs. 8 ... ... =		376 0 0	
7 @ Rs. 4 ... ... =		28 0 0	
		(a) 404 0 0	

	Rs. a. p.	Rs. a. p.
Amount written off Suspense Account by debit to Revenue Account :—		
Subscription for 1912-13 ...	317 0 0	
Do. for 1911-12 ...	8 0 0	
Advertisement	30 0 0	
		355 0 0
		1,507 1 1
Add—Closing balance		722 1 8
Total ...		2,229 2 9

	Rs. a. p.	Rs. a. p.
Subscriptions realised in advance for 1914-15— 2 @ Rs. 8 ... ... =	16 0 0	16 0 0
By Entrance Fee amount due— 9 @ Rs. 4	36 0 0	36 0 0
By sale of Journals		28 8 0
,, Contribution from H. E. the Governor ...		500 0 0
,, Miscellaneous		4 4 0
,, Interest on debenture		5 13 6
,, Misc. Donation		6 0 0
Actual Receipts ...		1,460 9 6
Add—Unrealised subscriptions as (*a*) by debit to Suspense Account		404 0 0
		1,864 9 6
Add—Opening balance of Revenue Account for 1913-14		364 9 3
Total ...		2,229 2 9

U. L. BANERJEE,
Treasurer.

II. *General Balance Sheet on 30th Sept. 1914 as modified.*

LIABILITIES.	Rs. A. P.	ASSETS.		Rs. A. P.
		Capital Account—		
Sundry Creditors—		P. T. Debenture for Rs. 100 ...		100 0 0
		Library Stock of Books	481 10 2	
		Deduct 5% depreciation charged to Revenue Account	24 1 4	457 8 10
		Value of Telescope (as assessed by the Director of Instruments) ...	142 8 0	
Revenue Account— Balance of Revenue Account ...	722 1 8	*Deduct* 5% charged to Revenue Account ...	7 2 0	135 6 0
Library Account— Balance of Library Account ...	128 5 5	*Furniture*— Last year	127 5 3	
Deposit Account— Balance of Deposit Account ...	165 6 6	*Deduct* 10% depreciation charged to Revenue Account	12 11 9	114 9 6
At Home Account— Balance of At Home Account ...	-22 15 9	*Unsold Journals*—		
		1910-11 ...	1,942	
		1911-12 ...	2,122	
		1912-13 ...	2,700	
		1913-14 ...	700	
			7,464	
		@ As. 2 per copy ...		933 0 0
	992 13 10	*Sundry Drs.*— (Unrealised assets as per Suspense Account 1913-14)—		
		Subscription for 1913-14 ...		404 0 0
Excess of Assets over Liabilities ...	1,904 1 7	Cash Balance in the Alliance Bank of Simla, Ld. ...		743 14 10
		Cash with Treasurer ...		8 8 3
	2,896 15 5			2,896 15 5

U. L. BANERJEE,
Treasurer.

The President's Address.

The End of the World—a Collision in Space.

Standing as we do in the shadow of the greatest war the world has seen, a calamity that came upon us with startling suddenness, we may be pardoned if our thought should dwell for a few moments on the chances of cosmic catastrophe, one for example that would destroy the world. There have been several prophecies dealing with the end of the world. One of the best known is that contained in the second Epistle of St. Peter, in which he says :—

"But the heavens and the earth, which are now, by the same word are kept in store, reserved unto fire against the day of judgment and perdition of ungodly men. But the day of the Lord will come as a thief in the night, in which the heavens shall pass away with a great noise, and the elements shall melt with fervent heat, the earth also and the works that are therein shall be burned up."

The authenticity of the second Epistle of St. Peter has been widely questioned. Origen remarked that one Epistle was left by Peter, but with respect to the second he said that "There is some doubt." Irenaeus only mentions one Epistle of Peter, and Eusebius reckoned the second Epistle among the books of the New Testament of disputed authority. Perhaps it does not matter to us whether it was written by St. Peter or not; for centuries it has been attributed to him, and is believed to be an inspired prophecy.

Another prophecy is that of Isaiah who said : "Moreover the light of the Moon shall be as the light of the Sun, and the light of the Sun shall be sevenfold, as the light of seven days."

In the Mahabharata there is a prophetic passage which deals with the end of the world as follows :—

"O King, towards the end of those thousands of years constituting the four *yugas*, and when the lives of men become very short, a drought occurs extending for many years, and then, O Lord of the Earth, men and creatures, endued with small strength and vitality, becoming hungry, die by thousands. And then, O Lord of men, seven blazing suns, appearing in the firmament, drink up all the waters of the earth that are in the rivers or seas. And, O Bull of the *Bharata* race, then also everything of the nature of wood and grass that is wet or dry is consumed and reduced to ashes.

And then, O Bharata, the fire called *Samvartaka*, impelled by the winds, appeareth on the earth that hath already been dried to cinders by the seven suns. And then that fire, penetrating through the earth, and making its appearance in the nether regions also, begetteth great terror in the hearts of the gods, the *Danavas* and *Yakshas*. And, O Lord of the Earth, consuming the nether regions, as also everything upon this earth that fire destroyeth all things in a moment."

There is no need to labour over the similarity between the seven suns mentioned in this passage and Isaiah's prophecy that the light of the sun shall be sevenfold. The number seven was peculiarly sacred from the earliest historical times, and would be not unlikely to appear in this way in a prophecy claiming credence, but the point in which all these prophecies are in agreement is that the world will be destroyed by fire, and it will, then, be interesting to us to consider how the destruction of the world by fire might come about.

The Earth's Internal Heat.

It occurs to us at once that the interior of the earth is hot, and that perhaps the internal heat might in some way come to the surface. In all deep mines the heat increases with the depth, and the temperature of the rock has been carefully observed in the deepest mines in order to find out at what rate the temperature increases with the depth. Observations in mines and boreholes exceeding 3,000 feet in depth, situated at places as far apart as Virginia, Lancashire, and Leipsic, the latter being 5,600 feet from the surface, showed that the heat increased by every 74 feet, 66 feet and 67 feet of depth, respectively. We have no idea whether this rate of increase continues, neither do we know how far in from the surface the maximum temperature is reached, but the increase appears to be uniform as far as our deepest observations go, and that is about a mile and a quarter, and we are therefore bound to assume that the same rate of increase continues for a further considerable distance. The increase in temperature, to the observed depths, amounts, we may say, to about 75 degrees or more for a mile of depth, and at this rate of increase we should reach the melting point of lead at a depth of 7½ miles, of iron at 15 miles and of platinum at 23 miles, and the temperature at which coke is transformed into graphite 4,000. Fahrenheit would be reached at 53 miles.

If the circle which I have drawn on the black board, two feet in diameter, represents the earth, the thickness of the chalk line represents a depth of about 100 miles, so that a depth of 53 miles is only a very little way into the interior of the earth, and it is very probable that the temperature continues to rise to a greater depth than 50 miles or even 100 miles. Whatever the temperature may be in the interior of the earth there can be no reasonable doubt that it is very high, quite sufficient to destroy everything on the globe if only it could reach the surface.

The weight or the rocks forming the crust of the earth with which we are acquainted is such that a cubic foot weighs from 150 to 180 lbs. Taking 170 lbs., as on average, one mile of thickness will give a pressure of 2¾ tons per square inch, and at a depth of 50 miles, the pressure is therefore over 130 tons per square inch and at 100 miles it must be 275 tons per square inch. At such pressures as these, rocks become plastic and even cold steel would flow, and the interior of the earth must consequently be fluid even if it were cold. But it is not cold, and the evidence of heat suggests that the temperature is so high that the ordinary substances we know are liquefied.

The combined effects, therefore, of pressure and heat must be such that under the crust the earth is fluid, and consequently, its structure must be in a condition of equilibrium, except for the comparatively small disturbances that take place in the crust. This explains how it is that earthquakes originate in the crust of the earth, and not at great depth, the greatest depth of origin of any earthquake is believed to be not more but probably less than 20 miles.

The question then arises as to whether any alternation in the existing conditions is likely, leading to a condition of unsuitable equilibrium, so that the interior hot materials could over flow the surface. The stresses set up in the crust of the earth by cooling are only likely to cause wrinkles, and there is nothing to suggest that the crust could ever break up, indeed its very weighty, and the plasticity of all but the surface of it, indicate that whenever any part of the crust reaches a condition of unstable equilibrium a settlement soon occurs, as is manifested in earthquakes. For anything more than this to appen the shape of the earth would have to be altered and the alteration would have to take place with some rapidity or the crust would settle down to suit the altering shape, the settlings being probably punctured by series of earthquakes. We may therefore be satisfied that there is nothing in the condition of the earth nor in the constitution of the solar system which gives any support to the idea that the world is likely to be destroyed by fire.

The Dark Stars.

Let us look beyond the solar system for a moment, and consider the stars, as they are called, which have appeared in various parts of the heavens from time to time.

On February 19th, 1901, a certain part of the constellation Perseus was photographed at Harvard, and the photograph showed all the Stars down to the eleventh magnitude. On the night of the 21st a new star was noticed in Edinburgh as between the second and third magnitude. In the next two days it became brighter than Capella. Its brightness therefore increased in about three days from less than the eleventh to the first magnitude, an increase in light of more than ten thousand times. In the case of this star we had clear evidence of the extraordinary rapidity with which a new star can blaze up, a rapidity that had always been suspected but in only one other case had been observed, and now that it was clear the change was sudden, explanations of the increase in light which otherwise seemed plausible had to be put aside, and the theory that it must have been due to a collision between the Star and another body has gradually gained ground.

Nova Persei, as the new star is called, was so bright that its light could be examined spectroscopically with ease and every detail of the character of the lines and bands was closely watched, and the changes in the constitution of the star and the movements of its gases were observed and noted. These appear to have been in agreement with what would have been expected if there had been a collision with another body, and as the proofs have accumulated it is now generally held that this is the most probable explanation of the apparitions of bright stars which have suddenly appeared in the sky.

We naturally at once ask ourselves what dark bodies there are in space and what are the chances of a collision. We know small dark bodies, which come into collision with the earth and appear as meteors when friction with the upper atmosphere causes heating. We are also well acquainted with larger dark bodies; all the planets are dark, and are only seen by the light they reflect from the Sun. There may be a very large number of dark bodies in space, bodies which having radiated their store of heat are now too cold to shine by their own lights. As far as we know, our Sun and all the stars are cooling in proportion as they are radiating their heat away into space, and as the stock of energy with which they commenced their career is gradually dissipated, the light and heat they radiate must be diminished until at length the heat is so much reduced that light is given off, and the star will be dark.

Among the stars we see many which seem to us to be waning, and to be in an older stage of radiation, indicating that they are further advanced in the process of cooling, and nearer to the time when they will be cold and dark. How many stars, large or small, have cooled down so far that they now emit no light, we have no means of knowing, but the number may be large, may be greater than the number of visible stars.

The Sun with his attendant planets is sweeping through space, and all the Stars are also each travelling through space with a considerable velocity and it is, therefore, possible that we may some day meet a dark body. If this dark body strikes the Sun or grazes the Sun, and if it is sufficiently large, the quantity of heat that would be generated would be so large that the hot envelope of the sun would be extended to an enormous extent, perhaps even engulfing the world, so that the inner planets would be absorbed into the blazing Sun.

If the force of the collision were somewhat less, so that the hot atmosphere of the Sun is only expanded to a comparatively small extent, the increase of the solar radiation would still be sufficient to vaporise all the water in the seas and to burn up every thing on the surface of the earth. It appears therefore that what has happened in the case of the new stars might happen to our sun as a result of a collision with a dark body and in that case the prophecy of St. James would be immediately fulfilled. If an approaching large body were to collide with the earth there would be the same evolution of heat and vaporising of all water and many of the less refractory substances, and the destruction of the earth would be practically instantaneous.

If a large body approached the Sun closely without actually touching it or touching any of the planets it would swing round the Sun and pass on into space in an orbit probably hyperbolic. In passing it would so disturb the Sun by its attraction that the deformation of the Sun would cause the evolution of a good deal of heat, perhaps enough to destroy the world, and if this body passed near the earth the deformation of the earth by its attraction of the rotating earth set up such stresses that the earth's crust would split and crumble and the tides would sweep round the earth over all the land.

How the Cataclysm would come.

It is evident that a celestial catastrophe is quite possible, and it may be interesting to inquire how long beforehand we should have any knowledge of the coming disaster. Suppose that we were to meet a body of the same mass as the Sun. Being cold and dark it would have become consolidated by shrinking as it cooled and it may be assumed to be a smaller dimension than the Sun, say about 550,000 miles in diameter about five-eighths of the Sun's diameter.

Such an object would appear as soon as it came near enough for the reflected Sun's light to illuminate its surface. It would seem to be about the 10th or 11th magnitude at a distance of 22,000 million miles and might then be photographed, and might be recognised as a near body as it would have a disc about twice the apparent diameter of Neptune, and rather more than that of Uranus.

Let us suppose that this object was approaching the Sun with an initial velocity the same as the velocity with which the Sun is travelling through space, say 10 miles a second. The approach of the dark Star would at first be almost limited to its own initial velocity of 10 miles a second, the attraction of the Sun would be very little felt.

For the next twenty years the dark Star would be coming nearer, always with slightly increasing speed, and at the end of that time it would appear as a star between the 5th and 6th magnitude, about as bright as Uranus, and plainly visible to the unaided vision. Being so much larger than Uranus it would be a very conspicuous object in the telescope, as it would be half as large again as Saturn. Long before this it would certainly have been discovered by the telescope, its large diameter noted, year after year its parallax and its increasing diameter, would have been measured, and the size of the body would be known, also the fact that it was approaching the Sun and by the time it became visible to the naked eye the date when it would reach the Sun's surface would have been calculated with some accuracy, and all the world would know of the coming disaster.

In another 4 years it would be about as distant as Neptune and would shine as a first magnitude star, but its apparent diameter would be about the same as that of Jupiter at his nearest.

In another year it would reach the distance of Uranus and would be brighter than any star except Sirius and Canopus, but its apparent diameter would then be half as large again as that of Jupiter so that in a telescope it would be a very fine object indeed. In one year more it would reach the same distance as Jupiter, and would shine with 100 times the light of Sirius, 5 magnitudes brighter. Its apparent diameter would be about six times that of Jupiter, about an eighth that of the diameter of the Moon. Then its progress being continuously more and more rapid, its speed would become so great that in a couple of months it would strike the Sun. In the last month, as it came near the Sun it would be a brilliant object in the sky. Approaching the Sun itself in brilliancy it would eventually be visible in broad daylight. Owing to the vaporisation of water and other substances its atmosphere would expand, and heavy clouds would form. Its apparent diameter would therefore considerably increase, as the clouds would reflect the sunlight and would hide its surface from view.

The Collision.

If the earth chanced to be in that part of its orbit at right angles to the line joining the centres of the sun and the dark star the sight at the moment of contact can be faintly imagined. Each sphere would bulge out to meet the other and their adjacent surfaces would fall together and mingle. In fifteen minutes after they touched, the smaller globe would have been completely engulfed in the larger whose substance would be splashed out. Some portions would probably leave the combined mass at such speeds that they would not return. The whole mass would be vapourised with an enormous evolution of heat. I have assumed that the dark star was approaching with the same initial velocity as that at which the Sun is travelling through space. If the velocity of the dark star were less the approach would be slower, and we should have longer warning.

The direction assumed, that in which the Sun is moving, would not bring the dark star near the earth, but if we suppose a dark body approaching from some other direction it might pass near the earth. The first result of this would be to deflect the earth from its normal path and its orbit might be reduced so that the earth would revolve round the Sun at a much less average distance, the distance at perihelion would be likely to be so small that the fierceness of the Sun's heat would destroy life, even if no collision of the dark star with the Sun or disturbance of the Sun's equilibrium caused an increase in the Sun's heat.

An approaching dark body might be very much smaller than we have assumed. Suppose that the dark body were the size of Jupiter. I twould then only become visible telescopically at 6,000 million miles, and to the naked eye at 3,000 million miles. From the time it became visible we should have about five years before it actually fell into the Sun. If it was only as large as Uranus, it would only become visible to the naked eye as Uranus is now visible, and would reach the Sun in three years from that time.

We are therefore bound, you see, to have some warning of a collision of a dark body with the Sun causing such an outburst as would destroy the world. The larger the dark body, the greater the collision, and the more extensive the final catastrophy, the longer our warning would be, extending to perhaps twenty or thirty years. On the other hand if the dark body were of the smallest size that by its direct collision with the sun could cause the evolution of enough heat to destroy the earth we might only have a couple of years of warning.

Dynamical Theory and Tidal Friction.

Questions regarding the tides have been recognised as being of the very first importance by great sea-faring nations like the English from the remotest antiquity. The ancients must have early discovered that there was a connection between the ebb and flow of the tides and the diurnal motion of the Moon. Cæsar shows us in his De bello Gallico that he possessed a rough and ready idea of that connection. He must have noticed that the intervals between the times of high water were equal to half those between the Moon's meridian passage. Of course he did not know that the Moon could cause high tides when on the meridian below the horizon. For high water is not produced merely under the Moon, but equally (or to be more accurate, almost equally) on the side of the Earth furthest removed from the Moon. These great tidal waves are separated from each other by ½ circumference of the Earth. As the Earth rotates, every part of its surface that is roughly in the same plane with the Moon, passes successively under these tidal waves. And then it is high tide at these particular places. But if the Moon's absolute attraction caused the tides, there would be only one high tide, whereas there are two tides daily. Again if the Moon's tidal force were equal on all the component parts of the Earth, there would be no tides at all. Why then are these two lunar tides (we are, for simplicity's sake at present neglecting the solar tides) daily? If the solid part of the Earth were fixed in space, and if the Moon were also fixed then there would be but one high-tide heaped up always under the Moon. But Earth and Moon are all the time tracing out ellipses round each other, or to be more accurate, around their common centre of gravity, which is about 3,000 miles distant from the Earth's centre, and so the conditions are quite different and more complicated. The great mathematician Newton was the first to give us anything like a rigorous theory of the tides. But he necessarily left this very difficult problem imperfectly solved. He showed that every particle of water on the Earth is attracted towards the Moon with a force proportional to her mass, and to the inverse square of her distance from the particle. Hence she attracts a particle nearest to her, more than a particle at the Earth's centre, and still more than a particle on the furthest side of the Earth away from her. Therefore she diminishes the Earth's attraction on any particle of water nearest her, and on any particle on the furthest side from her. Now, if you have two bodies not far apart, and attach to them two long strings, and if then you pull the strings towards you, you will thereby also pull the two bodies towards each other. And this accelerating force driving the balls together, varies in the ratio of the distance of the balls from each other, and the inverse ratio of the length of the strings. Thus the Moon's tidal force on the waters which lie at 90° from the common plane of the Earth and Moon reinforces the Earth's attraction there. But the Moon's contractive tidal force at these points is only $\frac{1}{2} \times$ her tidal differential or separative force above mentioned. Of course the Moon exerts a tidal force upon the Earth's matter as well as on the ocean, but the firmness of the Earth's solid matter destroys any apparent reaction to this force. But the fluid ocean is free to obey this tidal force, and thus to exhibit the change in its form. Now let us go more accurately and mathematically into the Moon's and Sun's tidal force on the ocean. We will, for the present confine ourselves to the tide-raising force of the Moon only. The attraction of the Moon on the Earth as a whole is the product of their masses divided by the square of their distance. Let M and m represent the masses of the Earth and Moon and c be the Earth's centre, and n be the point nearest the Moon, and f be the point furthest from her. Now the attraction by the Moon, on the Earth as a whole will be K $\frac{M\,m}{(m\,c)^2}$ the Earth moving with acceleration K $\frac{m}{(m\,c)^2}$ towards the common centre of gravity of Earth and Moon. Now at point n, the Moon's attraction will be K $\frac{m}{(m\,n)^2}$ and is greater than at c, because the denominator m n is less than m c. Hence the Moon tends to accelerate the point n more than the point c, and consequently tends to draw a particle at point n away from the Earth's centre. And this relative acceleration can be expressed by the formula 2k $\frac{m}{d^3}$. Again, at *f* the Moon's acceleration is $K\frac{m}{(m\,r)^3}$, and this is less than $K\frac{m}{(m\,c)^3}$ because the denominator m f is greater than m c. Therefore the Moon tends to draw away the Earth from the point f, or in other words, the Earth's attraction on f is diminished by the Moon's tidal force. Thus we have proved that water both at n and f tends to be separated from the centre of the Earth. We have said above that water at the points 90° from n and f tends to be driven towards the Earth's centre by the Moon's tidal force. Let p be the one point, and q the other. Then the Moon's accelerating force on p is $K\frac{m}{(p\,m)^3}$. This force can be conveniently resolved into its 2 components, which are parallel to c m and p c, respectively. But the component that is parallel to c m simply makes the particle at p move along with the rest of the Earth, and therefore produces no relative acceleration at all. Therefore it is only the 2nd component, *viz.* :—that which is parallel to p c, that has any effect on the relative acceleration of p. And this constrictive force can be represented mathematically by the formula $K\ m\ \frac{pc}{(pm)^3} = K\,m = \frac{p\,c}{(d)^3}\,K\ m\ \frac{r}{(d)^3}$. Similarly at *q* the Moon tidally attracts *q* with relative acceleration $K\ m\ \frac{q\,c}{(q\,m)^3} = K\ m\ \frac{q\,c}{(q)^3} = K\ m\ \frac{r}{(d)^3}$. Hence at either points p or q, a particle of the ocean tends to approach the Earth by a force $= \frac{Kmr}{(d)^3}$. Of course similar results arise from the attraction of the Sun, the solar wave tending to follow the apparent motion of the Sun, but to a much less degree, because this tide-raising force is in the ratio of the masses, but in the inverse triplicate ratio of the distances. And this distance in the case of the Moon is only 30 × Earth's diameter, but in the case of the Sun 12,000 × Earth's diameter.

The mathematical ratio of the two tide-raising forces of the Sun and Moon, respectively, can be shown thus—

$$\text{Moon} : \text{Sun} = g \times \frac{2 \times \frac{1}{80}}{(60)^3} : g \times \frac{2 \times 322{,}000}{(23{,}000)^3} = 5 : 2$$

(nearly). Thus although the Sun is so much heavier than the Moon, the proportion of the distances cubed is far greater than the simple proportion of their masses. The Moon's tidal wave is about 58 inches, that of the Sun only about 23 inches. Whilst gravity = 15 million × Sun's tide-raising force, it only = 6 million × Moon's tide-raising force, or about 4 million × tidal force of Sun and Moon together. As a matter of fact however, as the Earth is a spheriod of revolution and not a sphere, the Earth's gravity is more than 4 million ×

tidal force of Sun and Moon together, being nearer 5 million times greater. It can be calculated mathematically, that the Moon's tide-raising force $= \frac{1}{30}$ of her whole attraction, because it is as twice the Earth's radius divided by the Moon's distance, or $\frac{2}{60} = \frac{1}{30}$. And as the Moon's mass is $\frac{1}{80} \times$ Earth's mass and her distance $= 60 \times$ Earth's radius, therefore the fraction of the Earth's gravity represented by the Moon's differential tide-raising force $= g \times \frac{\frac{1}{30} \times \frac{1}{80}}{(60)^2} = g \times \frac{1}{8{,}640{,}000}$. And since the Moon's constrictive tide-raising force $= \frac{1}{2}$ her differential, her constrictive tide-raising force $= g \times \frac{1}{17{,}280{,}000}$. Thus if the constrictive force $= 1$, the differential will be 2, and there is a force altogether of 3 tending to make the water under the Moon higher than the water 90° distant. We can easily compare the tide-raising force of the Moon at points *n*, *c* and *f*. For the attraction of the Moon—

$$\text{at } n = g \times \frac{\frac{1}{80}}{(59)^2} = g \times 0{\cdot}00000359.$$

$$\text{at } c = g \times \frac{\frac{1}{80}}{(60)^2} = g \times 0{\cdot}00000347.$$

$$\text{at } f = g \times \frac{\frac{1}{80}}{(61)^2} = g \times 0{\cdot}00000335.$$

It is impossible however actually to observe by experiment the variations in the force of gravity due to the Moon's tidal force, owing to the fact that they are such very small quantities. Darwin thus failed to measure them experimentally, because other causes of far larger amounts interfered. It should be remembered that the tide-raising force due to the attraction of the Moon or Sun varies inversely not as the square but as the cube of the distance, as we have shown above by the formulas $2k \frac{m}{(d)^3} r$, (representing the differential force) and $k \frac{m}{(d)^3} r$ (the constrictive). This can easily be shown thus.

$$\text{Since attraction at } n = \frac{m}{(d-r)^2}$$

$$\text{and attraction at } c = \frac{m}{d^2}$$

$$\therefore \text{ tide raising-force at } n = m\left(\frac{1}{(d-r)^2} - \frac{1}{d^2}\right)$$

$$= m\left(\frac{2d\,r - r^2}{d^4 - 2d^3\,r + d^2\,r^2}\right)$$

$=$(Since r is very small compared with d) $m\frac{2r}{d^3}$. It may be interesting to compare the difference of the tide-raising forces of Moon and Sun at perigee and apogee. Since the eccentricity of the Moon's orbit is $\frac{1}{16}$, her distances at apogee and perigee are in the ratio of $(1+\frac{1}{16}):(1-\frac{1}{16})=17:15$, therefore the tide-raising forces are as $(17)^3:(15)^3$ = (about) 7 : 5. Since the eccentricity of the Sun's orbit is $\frac{1}{60}$, his distances at apogee and perigee are in the ratio of $(1+\frac{1}{60}):(1-\frac{1}{60})=21:19$. We have now investigated the amount and the ratios of Moon's and Sun's tidal-forces at the four cardinal points, *viz.*:—those in the plane of the attracting bodies, and those at 90° from these points. It now remains to enquire as to what will be the effect of these tidal forces at other points than the four cardinal points. The tidal forces will then be tangential forces tending to draw the water towards the plane of the attracting bodies. This tangential force is the resultant of two component forces, one of which is parallel to the direction of the attracting bodies and the other perpendicular to this direction. This force will then have the effect, not of raising or lowering the water, but of imparting to it a motion. Its amount and direction can be represented by the length and direction of the resultant diagonal, divided by the cube of the distance, thus :—$\mathrm{Km}\,\frac{\text{resultant diagonal}}{(d)^3}$. We have hitherto been chiefly considering the effect of the Moon's tidal-attraction, we will now consider the tides as due to both Moon and Sun. We have already shown that the Sun has its 2 tidal waves as well as the Moon (although in actuality they coalesce to form one ellipse) and that their ratios are as 7 : 3. At half Moons the Sun is at 90° or 6 hours from the Moon. The Sun is therefore pulling crosswise to or athwart the Moon, trying to make it high water when the Moon is trying to make it low water. But the Moon's tidal-force is $\frac{7}{3}\times$ Sun's tidal-force, and as the actual tide is then due to the difference of the 2 forces, the effect of the Sun is to lower the tide, so that it then rises and falls least, the height of the tide being then the difference of the lunar and solar tides. This is called "Neap tide." When the Moon is in syzygies (either new or full Moon) the Sun is then reinforcing her tidal-attraction and the result is the "Spring Tide", when the tide rises and falls most. The height is then equal to the sum of the solar and lunar tides. The height of the spring tide $=(1+\frac{3}{7})=\frac{10}{7}\times$ that of the lunar tide alone. The height of the neap tide $=(1-\frac{3}{7})=\frac{4}{7}\times$ the lunar tide. Hence the ratio between the spring and the neap tide $=\frac{10}{7}:\frac{4}{7}=10:4$. When however the Moon is neither at Syzygies nor quadratures, the Sun's tidal-interference with the Moon's tide is of a different nature at every period of the month, the actual high water is either accelerated or retarded by the Sun. Thus in the 1st and 3rd quarters of the Moon, the Sun will tend to pull the tide westwards of the lunar direction, when the time of high-tide will then be accelerated for us on the Earth's surface, and the opposite effect will take place in the second and last quarters, when the time of high-tide will be retarded. Because, when the two tidal waves do not coincide, their combined culmination must be at a point intermediate between them. Consequently the tide is not 49 minutes later every day, as it would be if it exactly followed the Moon, but some times it is as much as 11 minutes earlier than this 49 minutes period (*i.e.*, 24 hours 38 minutes) and sometimes later by 11 minutes (*i.e.*, 25 hours). This is called the priming and lagging of the tides. The approximate time of high water at any particular port in the afternoon of the day when the Moon is in syzygies is called the "Establishment of the Port." It represents the mean interval between the moment when the Moon crosses the Meridian, and the moment when it is high-water at that port. This interval depends upon local circusmtances, as to how the tide has to reach the place. Except for the interfering effect of wind and barometric pressure, this "Establishment of Port" is constant. This comparative lateness of high-tide is due to the interference with the free motion of the tide due to large continents, the narrowness of channels, their length and depth etc. At London the establishment of port is 1 hour 58 minutes, so that mean high tide occurs 1 hour 58 minutes later than the transit of the Moon, *i.e.*, when the Moon's hour angle is 1 hour 58 minutes or 29° 30′ angular distance from the meridian. By correcting for the priming and lagging of the tides the lunar time of high-water can be calculated for any phase of the Moon. It is very important for maritime purposes to make accurate observations in reference to the establishment of ports, and these observations unfortunately are sometimes made incorrectly, owing to observers often confusing the time of high-tide with the time of "Slack-water" which is quite a different thing, and means merely the time when the tide ceases to flow one way or the other. The heights of the spring and neap tides are proportional to the distances of Sun and Moon from the Earth. When both are in perigee, spring tides will be at their highest. When the Moon is in apogee, and the Sun in perigee, the neap tides will then be at their lowest. The Spring tides are greatest, we have said, when Sun and Moon are in perigee, but they are in reality still greater at the Equinoxes, when the Sun is on the equator and the Moon therefore necessarily only 5° from it, because then their pull is direct (that is not oblique). They are greatest of all, when (added to all these favourable circumstances) the Moon's nodes are at the Equinoxes, which happens every 9¾ years. The variation in the height of tides due to the declination of the Sun and Moon, is in consequence of the fact that the vertex of the tide wave tends to take its position immediately under or normal to the Sun and Moon, and thus when the Sun or Moon shifts North or South the tide must shift too. For example, if the Moon is in North declination, and the place on the Earth is in North latitude; of two consecutive tides, that which happens when the Moon is near the Zenith will be greater than that which happens when the Moon is near the Nadir, because the Moon's least Zenith distance is then less than her least Nadir distance. The difference will be greatest when Sun and Moon are in opposition and in opposite declinations. This is called the "Diurnal Inequality." These inequalities in height of the tides can be regarded as half periods, of a day or fortnight. But, after a fortnight the Moon's declination will have the same value but opposite sign. Hence a fortnightly tide. In the same way these inequalities in the heights of the tides can be referred to the Sun, being then semi-diurnal and six-monthly. When both the Sun's and Moon's declination is Zero, of course there is no such difference in the diurnal, fortnightly or half yearly tides. It is interesting to note that the first attempts at finding the relative masses of Sun and Moon were made by means of measurements of the relative heights of the Solar and lunar tides. Thus, if the spring tide anywhere is say 41 feet, and neap-tide is 15 feet, then the ratio between lunar and solar tide $= (41 + 15) : (41 - 15) = 28 : 13$. But tidal forces are proportional to the masses and inversely proportional to the cubes of the distances. Now the Sun's distance $= 385 \times$ Moon's distance. Therefore the Moon's Mass $= \frac{28}{13} \times \frac{1}{(385)^3} \times$ Sun's mass $= \frac{1}{26,500,000} \times$ Sun's mass, and as the Sun's mass is known by other means to be $324,000 \times$ Earth's mass, therefore the Moon's mass $= \frac{324000}{26,500,000} \times$ Earth's mass $= \frac{1}{81 \cdot 79} \times$ Earth's mass. Again if the ratio of the Sun and Moon's mass is known, then by a similar method the ratio of their distances can be calculated. We should mention here that in speaking of "diurnal" tides, reference is made not to solar, but lunar days, because the time of high tides depends upon the Moon's motion relative to the meridian, the sun merely modifying these effects. The lunar day is the interval occuring between two upper transits of the Moon across the meridian. And since $28\frac{1}{2}$ lunar days $= 29\frac{1}{2}$ mean solar days, therefore one lunar day $= (1 + \frac{1}{29\frac{1}{2}})$ mean solar days $= 1\frac{2}{57}$ mean solar days $=$ 24 hours $50\frac{1}{2}$ minutes. Besides irregularities in the tides due to the local configuration of the sea, base, and shore, etc., the tides are also affected by the state of the atmosphere and the wind. The rise of the tide is roughly in inverse proportion to the (height of the barometer). Thus a fall of the barometer of $\frac{2}{3}$ inch will correspond to a rise of the tide of about $\frac{2}{3}$ feet $=$ 8 inches. The ratio being about one foot for every inch of the mercury. Again the wind, if it blows into port, will make the tide rise often several feet above the normal. But then the tide will be delayed (curious as it may seem), because although the depth of the high water at the bar is reached before the proper time, yet the greatest depth is not attained till some time afterwards. And opposite effects take place in the opposite circumstances. If a tide has to run into a narrowing channel, it will attain a height much greater than the normal. If on the contrary the tide has to widen out into a large sea through a small channel (such as through the straits of Gibraltar into the Mediterranean), the tides will be almost imperceptible. It is very difficult to detect the tides in lakes or land-locked seas. Their height ought theoretically to be in the same ratio to the height of a mid-ocean-tide, as the length of the particular sea is to the length of the Earth's diameter. But practically this theoretical valuation is so much masked by the effects of wind and barometric pressure (which are far greater in their results) that it necessitates a long series of careful observations to separate real tides from the effects of these other causes. Tides travel up rivers at a rate proportional to the depth of the river, the amount of friction encountered by the rivers's bed, and the river's velocity. It usually ascends the river as far as the point where the velocity of the river $=$ the velocity of the tide. At this point it will be "slack water," as we before mentioned. It is the point where anything on the river's surface would cease to float upwards. The tidal velocity in rivers is something between 10 and 20 miles an hour, and it will attain a height far greater than the apex of the tide at the river's mouth. We have hitherto been treating chiefly of the great ocean in its statical aspect, *i.e.*, as forming the figure of a prolate spheriod around the Earth (this prolate spheriod being generated by the revolution of the ocean's ellipse about its major axis), which points in the direction of the tidal attraction. This no doubt would be a perfectly accurate description of the form which the ocean would assume, if the Earth did not rotate. But when we take into account at the same time the Earth's rotation, we find that the form of the ocean's surface is greatly modified thereby, and instead of the major axis of the prolate spheroid pointing towards the Moon, we learn on the contrary the surprising fact that it would be low tide in direction of the tide-raising force and high tide at 90° angular distance from it. However, whether the Earth rotated or not, the tide-raising bodies would always tend to draw the water away from the poles towards the equator. Moreover from the equilibrium theory of the tides, certain useful deductions can be made. For example, the height of the tide is proportional to the ratio of the tide raising force to gravity, and hence inversely proportional to the intensity of gravity, which is itself proportional to the density of the Earth. Another mathematical consequence is, that the height of the tide is proportional to the Earth's radius, because both the intensity of gravity and the intensity of the tide-raising forces are themselves proportional to the Earth's radius. We are thus enabled to calculate tidal quantities on different celestial bodies. For if M represent the mass of the attracting body and R its distance, and r represent the radius of the body whose tides we are considering and d its density, then we have the formula $\frac{Mr}{d\,R\,3}$ to denote the height of the tide on that particular body. But as we have said this statical theory of the tides is wholly incomplete, because it fails to take into account the fact that the Moon and Sun besides merely raising the tides, have to keep up their motion round the Earth, in the opposite direction from its rotation (*viz* :—from East to West). The statical theory also fails to take into account the fact, that a tidal wave has impetus of its own. This impetus varies according to the depth of the water and the force of gravity, and the amount of friction it has to encounter. The dynamical theory then which takes into account all these things is a much more complicated and difficult problem. But what has been said above in connection with the statical theory is absolutely necessary to be thoroughly comprehended before we can understand the true dynamical theory. Now if the Earth had no continents, but was entirely covered with water, the tidal waves would travel round the globe at a constant velocity. And this velocity would be the apparent velocity of the Moon, the vertex of the tidal wave keeping always under her, if the depth of the water were as much as or more than 14 to 12½ miles. If the depth were less than 12½ miles, the tidal wave would travel 90° behind the Moon, whilst the water near the poles, since it has a far less distance to travel in each rotation than the water at the Equator would still be able to keep up with the Moon. There would thus be a neutral latitude of tideless water between these two extremes. We must however distinguish between a wave whose motion is one of "forced" or on the other hand "free oscillation." If an earth-quake should suddenly disturb the ocean and then the wave generated were to be left to take its own course, this would be an instance of "free oscillation." In this case it can be mathematically proved that its (velocity)^2 will vary in the ratio of the depth of the ocean, and will be given by the formula $v^2 = gh$ or $v = \sqrt{gh}$, which is the velocity which a body would acquire in its fall through the depth of the ocean. Thus in a depth of water of say 100 ft. the wave's velocity would be = 40 miles an hour, and in 10,000 ft. would = nearly 400 miles an hour. Now as the Moon passes daily from over the continent of America into the Pacific ocean, she generates after the manner of a forced oscillation an initial tide in the Pacific. The wave then continues its course much after the manner of a free wave, but not quite, since the Moon still accelerates it, because she travels slower than does the surface of the Earth at the Equator, and therefore relatively Westwards. Another tide wave is generated by her in the same place 12 hours later when she is on the meridian below the horizon. It also commences as a forced and continues merely as a free oscillatory wave. If we enquire more accurately into the manner of the tidal wave's motion round the globe, we notice that in the first and third quadrants of the Earth's equatorial circumference, the Moon's tidal attraction will pull the wave in a direction contrary to that of the Earth's rotation, and in the 2nd and 4th quadrants the Moon will pull in a similar direction to the Earth's rotation. Therefore after the first and third terrestrial quadrants the wave will be going comparatively slowly (having been retarded by the Moon), but after the 2nd and 4th quadrants, the wave will be going at its fastest, having been accelerated by the Moon. Thus at quadratures the wave will be travelling slowly, and at Syzygies it will be travelling fast. And if the water be travelling fast (say for simplicity's sake) in a uniform canal it must be shallow when it is travelling fast, and deep when it is travelling slowly. But as we have shown, the place where it is travelling fast is in the direction of the Moon, and when it is travelling slowly is at 90° to that direction. Therefore from the dynamical theory of the tidal motion, we arrive at a result which is the exact opposite from the result obtained on the statical theory, *viz* :—that under the Moon it will be lowtide, and at 90° from the Moon it will be hightide. This dynamical theory however, though being nearer the truth than the statical theory, does not give a result which is absolutely and mathematically correct in fact, owing to the extensive complications that arise from the varying depths of the ocean, etc., etc. Supposing for simplicity's sake, the tidal wave to be running in a canal round the world of constant depth and width, let us see the results. You will easily perceive that the deeper the canal, the greater the amount of water lifted in any vertical column by the Moon, because more water is displaced in the case of a deep vertical column than a shallow one : and hence the more it will be elevated relatively to the water at its side. Now the only way the raised water is able to fall again to the normal level of the ocean, is by pushing forward and upward its adjacent column. And hence the motion of the tidal wave depends upon the ratio of the height of the tidal wave to the normal height of the surface of the ocean. And this depends upon the depth, as I stated above. To keep up with the Moon the tidal wave would have to travel over 1,000 miles an hour, which would necessitate a depth of from 12 to 14 miles. But the sea is nowhere anything approaching this depth, being nowhere probably deeper than 5 miles. And this would give a velocity of only 600 miles an hour, even if it were as deep as 5 miles all over. In other words gravity is quite unequal to the task of making the tidal-wave keep pace with the Moon, except perhaps very near the poles.

Let us now consider what is the motion of any individual particle composing the tidal-wave. When a particle is above the mean level of the ocean, it will be advancing, since the wave is produced by the pushing of a whole vertical column of particles. But when the particles are below the mean level, they are then receding. Hence, an individual particle describes a long ellipse. If, however, the water has an independent current of its own, the ellipse will travel along in company with the current either backwards or forwards. The velocity of any individual particle can be mathematically calculated. It bears the same ratio to the velocity of the tidal-wave, as the wave's height above the mean level of the ocean bears to the whole ocean's depth. We will now enquire more fully into the components of the Moon's tidal-attraction. At the four cardinal points, *i.e.*,the two points in the Moon's plane (or at 0° and 180°), and the other two points at 90° and 270°, the water is pulled neither East nor West by the Moon's action. But between these points and most of all at the half-quarters, the force is tangential towards the plane of the Moon. Therefore at these half-quarter points, the tidal-wave cannot rest in equilibrium, for it is being pulled backwards or forwards by the tangential force. And this tangential force is counteracted by no other force, since, gravity is indifferent to motion forward or backward along the Earth's circumference. And herein lies the most glaring defects of the statical theory when taken alone, in that it absolutely neglects this tangential force which is really the most important force of them all, because it is quite independent of gravity. Thus whilst the tidal wave cannot keep under the Moon, it cannot remain (owing to tangential force) at any point from there up to 90°. Hence, not only, as we have said above, the true dynamical theory of the tides proves that it is low water under the Moon but it proves the still more startling fact, that the particles of the water under the Moon are flowing backwards, because water below the level of the advancing wave flows backwards in an elliptical curve, though of course much more slowly than the tidal-wave advances. The only matter that remains to be noticed, is the effect of friction, which is always acting as a drag upon the motions of the water. We have showed above that the head of the tidal prolate spheroid cannot remain in a line with the Moon, nor owing to tangential force can it lie between that point and 90° Eastwards. But even at 90° from the plane of the Moon's direction, the wave cannot remain, because being a cardinal point, there is no tangential force there and gravity exerts no influence backwards or forwards, but the water is advancing with its greatest velocity there, and therefore meets with the greatest amount of friction in opposition. Consequently friction unopposed by any other force would carry the major axis of the tidal prolate spheroid still further back than 90°. But between 90° and 180°, both friction and tangential force would continue to urge the wavehead still further backwards, and so it cannot stay there. And as we have seen above, it could not stay at 180°. But it can at last find a resting place, so to speak, between 180° and 270°, because at a point intermediate (say 225°), friction is acting backwards or Eastwards with the Earth's rotation, and the tangential force is acting Westwards, and so from these two forces in opposition, equilibrium is at last attained. Thus according to the true dynamical theory, the wave-head of the tidal spheroid has fallen back, 225° from the Zero point facing the Moon, which was the position which according to the statical theory it should have assumed. And this looks for all practical purposes (because for practical purposes, it is of no consequence what particular end of the major axis points in either direction) as though the wave-head had only fallen back 45° from the direction of the Moon. We will next consider the actual course of a tidal wave. It is as follows. It starts on the West coast of South America, and travels West through the deepest water of the Pacific Ocean at a rate of 850 miles an hour, so that the tidal-wave reaches New Zealand in about 12 hours from the start. It then passes on by Australia through the Indian Ocean and arrives at the Cape of Good Hope in 29 hours. It then enters the Atlantic and verges towards the North at about 700 miles an hour. It arrives at Florida in about 40 hours from the start. But in order to get to London it has to go round the North of Scotland and then southwards through the North Sea, and arrives there in 58 hours from the start. Hence in the great oceans there are four great tides following each other at the same time, and nearly in the same paths. Their paths are however modified continually by the changing declination and distances of Sun and Moon. In the middle of the great oceans the height of the tidal-vertex is not more than 2 or 3 feet, but on the continental shores it is a great deal more pronounced. And in bays which narrow very rapidly (for example the Bay of Fundy) the tide is nearly 100 ft. At Bristol it is 50 ft. The shallower the bottom, the less will be the velocity and the greater will be the height of the tidal-wave. The height of the tidal-wave varies theoretically inversely as the fourth root of the depth. But this theoretical calculation is greatly modified in practice, by tides interfering with one another. For example, when a tidal wave beats up against a coast, specially if the water be deep there, it will be reflected for a very considerable distance back again into the ocean, and will meet the next tide coming in. And these so-called "interferences" greatly vary the height of the tides even at places comparatively near to each other. Again there are places, where the tide comes in by two different routes. For example on the East coast of England the tide not only comes round by the North of Scotland, but in a minor degree also up the English Channel. This has the effect of producing tides at some places of twice the normal height, and at other places the tide is reduced to almost nil. We must not forget to mention a most important scientific fact, which is proved by the action of the tides, namely that the Earth's interior core is exceedingly rigid; a fact which goes clean against the theories of the geologists, who held that the interior of the Earth was a viscous molten mass. The Earth's rigidity is proved in this way. If the Earth's core were viscous, it would yield somewhat to the tidal-attracting forces. And if it yielded the tides would be diminished. But the most careful observation shows that the tides are not diminished by the minutest fraction from what they ought to be if the Earth were as rigid as steel. Now we must consider the very interesting results which follow from tidal-friction. As the Moon revolves 27½ times slower than the Earth from West to East, she of course moves relatively to the Earth's rotation in a direction East to West, tending to drag the water of the ocean (or rather a portion of it) in a direction contrary to that of the Earth's rotation. Thus friction is set up between the Earth's surface and the ocean. Hence whatever water stays behind with the Moon must retard the Earth's rotational velocity. This is due to the fact that liquids are viscous, and resist change of form, and in doing so convert part of their kinetic energy into heat. Owing to this friction, the Earth's rotating surface drags the water along with it, whilst the Moon drags the water back. Hence a couple is formed, which tends to diminish the angular velocity of the Earth's rotation. If the tidal motion consisted merely in the small variations of height twice a day in mid-ocean, tidal friction would be a quite negligible factor. The case is quite different however, when we consider the action of the tides against the continents. Here immense waves of water flow with great friction against the shores involving a great amount of energy which has to be made up for by the expenditure of an equal amount of energy from the Earth's rotating motion. This means a lessening of rotational velocity. As the amount however is really comparatively very small, the length of the day is affected to only a very small extent. The day cannot be more than $\frac{1}{10,000}$ second of time longer than it was a hundred years ago. This excessive minuteness of the retardation of the Earth's angular velocity is no doubt due to the fact that there is another cause which acts in an opposite direction tending to *accelerate* the Earth's velocity. For the fact that the Earth is always giving out heat into space, means that the Earth is always contracting, and hence the Earth's radius is diminishing and hence (as far as this cause is concerned) its angular velocity is increasing. However the frictional cause on the whole preponderates, resulting as we have said in the Earth's rotation being diminished by $\frac{1}{10,000}$ of a second in a century. But if the Moon exerts a couple on the Earth, it is obvious that the Earth will exert a counter couple on the Moon. Now the Earth's rotating surface tends to carry the head of the major axis of the tidal spheroid Eastward of the Moon, and since the particles there are nearer to the Moon than the particles at the other end of the major axis, the tidal head tends to pull the Moon forward or Eastward, and hence increases her velocity, and her distance (because her areal velocity remains the same) and her period. Thus the month is lengthened by tidal friction, as well as the day. Now, since the Moon's distance from the centre of gravity of Earth and Moon is far greater than the distance of the ocean from its axis of rotation which passes through the centre of the Earth, the effect of tidal friction upon the Earth's rotation is far greater than it is upon the Moon's orbital motion. Hence the final effect of tidal friction is to make the day equal in length of time to the month. Hence after many millions of years to come, the day and the month will be equal, and it can be calculated mathematically that they will both be 1,400 hours long. The Earth will then always present the same hemisphere to the Moon, and lunar tides and lunar tidal friction will then have ceased. But solar tidal friction will still continue. And its effect will be to continue to diminish the Earth's rotatary velocity. And it will have the opposite effect upon the Moon's orbital motion from what the lunar tide had, namely to retard instead of accelerate her velocity and to diminish instead of increase her distance. The Moon will thus ultimately rejoin her parent Earth, and owing to the immense gravitational pressure which will then be set up between Earth and Moon, will to a certain extent coalesce with the Earth, and the two bodies will together form one somewhat misshapen ellipsoid. The last step will be when the rotation of this Earth-Moon body or in other words its day, will coincide with its year, and will follow the example of the two inner planets Mercury and Venus in turning always the same face to the Sun, one hemisphere remaining in eternal day and the other in eternal night.

Observation of the Transit of Mercury, 7th November 1914,

By R. J. Pocock, B.A., B.Sc., F.R.A.S.,
Director, Nizamiah Observatory,
Hyderabad.

At Hyderabad the first and second contacts alone were visible, the third and fourth taking place after sunset.

It was intended to make observations of both 1st and 2nd contact with the finders of both the 15 inch Grubb visual and 8 inch Cooke photo-visual telescopes. The first contact, however (always a difficult observation), was not observed and the 2nd contact was only observed with the finder of the 8 inch Cooke photo-visual, aperture 2½ inches. The observation was made by Mr. T. P. Bhaskaran Shastri, Assistant, with a pocket chronometer belonging to the Director which was compared immediately after with the standard (Cooke) sidereal clock of the Observatory.

	hour.	minute.	second.
The observed Indian Standard time was—	15	29	36·81
The computed time	15	29	35·21
Difference	...	...	1·60

In computing the time of second contact the geographical co-ords of the Observatory (which have never been accurately determined and may well be slightly in error) were taken to be Grocentric Latitude +17° 19′ 20″

East longitude 5*h*. 13*m*. 37·66*s*.

HYDERABAD, *10th November*, 1914.

Memoranda for Observers.

for the month of December 1914.

(Standard Time of India is adopted in these Memoranda.)

Sidereal Time at 8 p.m.

			H.	M.	S.
December 1st ...	...	...	0	38	25
,, 8th ...	...	...	0	6	1
,, 15th ...	...	...	1	33	36
,, 22nd...	...	...	2	1	12
,, 29th ...	...	...	2	28	48

From this table the constellations visible in India during the evenings in December can be ascertained by a reference to a star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

The Moon.

PHASES—

December	2	at	11-51 P.M.	Full Moon.
,,	10	,,	5-2 ,,	Last Quarter.
,,	17	,,	8-5 A.M.	New Moon
,,	24	,,	1-55 P.M.	First Quarter.

OCCULTATIONS—

December	9	at	7-22 A.M.	Regulus	between	20° N.	&	66°S.
,,	20	,,	10-55 ,,	Uranus	,,	30° S.	,,	90°S.
,,	21	,,	7-2 ,,	Jupiter	,,	49° N.	,,	32°S.
,,	31	,,	5-40 ,,	Nath	,,	2° S.	,,	62°S.

CONJUNCTIONS—

December	4	at	4-14 P.M.	with	Saturn	(Planet	5° 29′ S.)
,,	15	,,	3-30 ,,	,,	Venus	(,,	7·36 N.)
,,	16	,,	1-52 ,,	,,	Mercury	(,,	4·56 N.)
,,	17	,,	11-28 A.M.	,,	Mars	(,,	3·47 N.)
,,	21	,,	7- 3 ,,	,,	Jupiter	(,,	0·12 S.)
,,	31	,,	6-51 P.M.	,,	Saturn	(,,	5·31 S.)

The Planets.

Mercury is a morning star, rising in Libra about an hour before the sun at the beginning of the month, but diminishing his distance as the month advances, as he approaches superior conjunction which will occur on the 5th of January.

Venus also is a morning star, rising in Scorpio about half an hour before the sun on the 1st, and nearly three hours before on the 31st having by that time retrograded into Libra.

Mars is an evening star until the 24th when he will be in conjunction with the sun. He will be too near to the sun to be visible at any time during the month. Position on the 15th, R. A. 17·38 Dec. 24° 1′ South.

Jupiter also is an evening star in Capricornus, setting about four hours after the sun on the 1st and about three hours after on the 31st. Position on the 15th, R. A. 21·27 Dec. 15° 56′ South.

Saturn will be in opposition to the sun on the 21st, and therefore on the meridian at midnight on that date. Position on the 15th, R.A. 5·57 Dec. 22° 17′ North, on the line between Taurus and Gemini.

Uranus is in Capricornus. Position on the 15th, R. A. 20·46 Dec. 18° 36′ South.

Neptune is in Cancer. Position on the 15th, R. A. 8·8. Dec. 19° 47′ North.

Memoranda for Observers

for the month of January 1915.

Standard Time of India is adopted in these Memoranda.

Sidereal Time at 8 p.m.

					H.	M.	S.
January	1st	...	...	...	2	40	38
,,	8th	...	...	...	3	8	14
,,	15th	...	...	...	3	35	50
,,	22nd	...	...	...	4	3	26
,,	29th	...	...	...	4	31	2

From this table the constellations visible in India during the evenings in January can be ascertained by a reference to a Star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

The Moon.

PHASES—

January	1st at	5-10 P.M.	Full Moon.
,,	9 ,,	2-30 A.M.	Last Quarter.
,,	15 ,,	8-11 P.M.	New Moon.
,,	22 ,,	11-2 A.M.	First Quarter.
,,	31 ,,	10-11 ,,	Full Moon.

OCCULTATIONS—

Jan.	5th	at	12-57 P.M.	Regulus	between	8°N. & 78° S.
,,	12th	,,	4-11 P.M.	Antares	,,	4°S. & 79° S.
,,	27th	,,	1-45 P.M.	Nath	,,	5°N. & 58° S.

CONJUNCTIONS.—

Jan.	12 at	4-51 P.M.	with	Venus	(Planet 9° 42′ N.)
,,	15 ,,	9-22 A.M.	,,	Mars	(,, 2° 23′ N.)
,,	16 ,,	8-27 A.M.	,,	Mercury	(,, 0° 8′ N.)
,,	18 ,,	4-8 A.M.	,,	Jupiter	(,, 0° 54′ S.)
,,	27 ,,	11-29 P.M.	,,	Saturn	(,, 5° 37′ S.)

There will be no lunar eclipses this year. The Moon will enter the Penumbra of the Earth, but not the Umbra on the 31st at 10-30 A.M.

The Planets.

Mercury will be in superior conjunction with the sun on the 5th and will then become an evening star. He may be visible towards the end of the month if the western skies are clear; setting about an hour after the sun. He will be in conjunction with Mars at half an hour after midnight on the 1st.

Venus is a morning star rising a little more than three hours before the sun throughout the month. She will be at her greatest brilliancy on the 2nd when she will be found in the constellation of Ophiuchus, R.A. 17·42 Dec. 19° 35′ S.

Mars also is a morning star and will so remain throughout the year. He will be too near to the sun to be visible this month. Position on the 15th, R.A. 19·30th Dec. 23° 3′ S. in Sagittarius.

Jupiter is an evening star until the 24th when he will be in conjunction with the sun in Capricornus. Position on the 15th, R.A. 21·52 Dec. 13° 51′ S. setting about two hours after the sun.

Saturn is an evening star, retrograding in Taurus. Position on the 15th, R.A. 5·46 Dec. 22° 19′ N. The rings of this planet are now attaining their apparent maximum width.

Uranus in Capricornus. Position on the 15th, R.A. 20·53 Dec. 18° 10′ S.

Neptune in Cancer. Position on the 15th, R.A. 8·5 Dec. 19° 57′ N.

The Sun is at perigee on the 2nd at 11-30 P.M.

Memoranda for Observers

for the Month of February 1915.

Standard Time of India is adopted in these memoranda.

Sidereal Time at 8 p.m.

			H.	M.	S.
February 1st ...	...	...	4	42	51
,, 8th ...	...	...	5	10	27
,, 15th ...	...	...	5	38	3
,, 22nd ...	...	...	6	5	39
,, 28th ...	...	...	6	29	18

From this table the constellations visible in India during the evenings in February can be ascertained by a reference to a Star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

The Moon.

PHASES—

February 1	at	10-41	A.M.	Last Quarter.
,, 14	,,	10-1	,,	New Moon.
,, 22	,,	8-28	,,	First Quarter.

OCCULTATIONS—

February 1	at	7-44	P.M.	Regulus	between	4°N. & 78°S.
,, 8	,,	10-43	,,	Antares	,,	9°S. 90° S.
,, 23	,,	10-24	,,	Nath	,,	7°N. & 55°S.

CONJUNCTIONS—

February 10	at	5-13	P.M.	with	Venus,	(Planet	7°30′N.)
,, 13	,,	9-35	A.M.	,,	Mars	(,,	0°24′N.)
,, 15	,,	1-57	,,	,,	Jupiter	(,,	1°37′S.)
,, 15	,,	8-43	,,	,,	Mercury	(,,	2°5′N.)
,, 24	,,	6-44	,,	,,	Saturn	(,,	5°35′S.)

The Planets.

Mercury is an evening star until the 21st when he will be in inferior conjunction with the sun. He will be at greatest elongation East on the 6th at 12-30 P.M., and may be visible during the first week of the month, setting in Aquarius about an hour later than the sun. He will be in conjunction with Jupiter at 12-18-P.M. on the 2nd.

Venus is a morning star, rising about three hours before the sun throughout the month, and moving from Ophiuchus to Sagittarius during the first week. She will be at greatest elongation west on the 6th at 10-30 P.M.

Mars also a morning star, rises less than an hour before the sun throughout the month. Position on the 15th, R.A. 21, 1 Dec. 18° 1′S.

Jupiter is an evening star until the 24th when he will be in conjunction with the sun. During the first week of the month he will set about an hour later than the sun. Position on the 15th, R.A. 22° 20 Dec. 11° 20′S. in Aquarius.

Saturn an evening star is retrograding in Taurus. Position on the 15th, R.A. 5·41 Dec. 22° 21′ N.

Uranus in Capricornus. Position on the 15th, R. A. 21·0 Dec. 17° 40′ S.

Neptune in Cancer. Position on the 15th, R. A. 8·1 Dec. 20° 8′ N.

The Sun.

There will be an annular eclipse of the Sun on the morning of the 14th, but it will not be visible in India. It will begin on the earth generally at 7-11 A.M. in Longitude 59° 42′ East and Latitude 31° 36′ South, and will end at 12-54 P.M., in Longitude 159° 12′ East and Latitude 17° 12′ North.

Memoranda for Observers

for the month of March 1915.

Standard Time of India is adopted in these memoranda.

Sidereal Time at 8 p.m.

		H.	M.	S.
March	1st	6	33	15
,,	8th	7	0	51
,,	15th	7	28	27
,,	22nd	7	56	2
,,	29th	8	23	38

From this table the constellations visible in India during the evenings in March can be ascertained by a reference to a Star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

The Moon.

PHASES—

March	2	at	12-2	A.M.	Full Moon.
,,	8	,,	5-57	P.M.	Last Quarter.
,,	16	,,	1-12	A.M.	New Moon.
,,	24	,,	4-18	,,	First Quarter.
,,	31	,,	11-7	,,	Full Moon.

OCCULTATIONS—

March	1	at	4-39	A.M.	Regulus	between	5° N. & 78° S.
,,	8	,,	4-4	,,	Antares	,,	8° S. & 86° S.
,,	21	,,	9-35	,,	The Pleiades	,,	71° N. & 58° N.
,,	28	,,	3-20	P.M.	Regulus		1° N. & 78° S.

CONJUNCTIONS—

March	12	,,	7-2	A.M.	with Venus	(Planet 3°0′ N.)
,,	13	,,	6-59	P.M.	,, Mercury	(,, 0°20′ ,,)
,,	14	,,	12-2	,,	,, Mars	(,, 1°59′ S.)
,,	14	,,	10-43	,,	,, Jupiter	(,, 2°20′ S.)
,,	23	,,	4-8	,,	,, Saturn	(,, 5°22′ S.)

The moon will enter the Penumbra of the Earth, but not the Umbra, at 12-30 A.M. on the 2nd .

The Planets.

Mercury is a morning star, rising in Capricornus about an hour before the sun on the 1st and attaining greatest elongation west 27° 43′ on the 20th. He will be visible in clear skies throughout the month. He will be in conjunction, 1° 18′, to the south of Jupiter on the morning of the 30th.

Venus a morning star, rises in Sagittarius about three hours before the sun on the 1st. She moves through Capricornus and into Aquarius before the end of the month, when she will rise about two hours before the Sun.

Mars also a morning star, rises about an hour before the sun throughout the month. Position on the 15th, R. A. 22·27 Dec. 10° 50′ South. He will be in conjunction with Jupiter on the morning of the 24th, only one-fifth of a degree separating the two planets.

Jupiter now a morning star, having been so lately in conjunction with the sun, will only be visible by about the middle of the month. Position on the 15th, R. A. 22·45 Dec. 8° 52′ South in Aquarius.

Saturn an evening star in quadrature with the sun on the 17th. Position on the 15th, R. A. 5·41 Dec. 22° 18′ North now travelling eastwards again in Taurus.

Uranus in Capricornus. Position on the 15th, R. A. 21·6 Dec. 17° 15′ South.

The Sun.

The Sun will enter the sign of Aries at 10-21 P.M., on the 21st being the vernal equinox.

The Journal of the Astronomical Society of India.

VOL. V.] SESSION 1915-1916. [NOS. 4, 5 & 6.

Report of the Meetings of the Society held on Tuesday, 26th January 1915, Tuesday, 23rd February 1915, and Tuesday, 30th March 1915.

THE minutes of proceedings of the meetings were read and confirmed, and the publications received from other Societies were announced and votes of thanks accorded to the donors.

The papers read at these meetings are published in this issue.

In the issue of the last number of the Journal for November and December 1914 the name of the Author of the paper on "Dynamical Theory of Tides and Tidal Friction" was omitted in error. Apologies are now expressed to the Author the Revd. A. C. Ridsdale, M.A., F.R.A.S., F.R. Met. Soc., M. LOND. MATH. S., F.Ph.S., A.L.C.M., Foreign Member of Sociétié Astronomique de France.

A Short Paper on Comet 1913 F (Delavan)

BY P. C. BOSE, ESQ.

SOME months ago public interest was roused by the appearance of a comet in the region of the constellation Ursa Major during the early hours of the morning. The comet was considered ominous because it happened to appear just at a moment when our little planet was being convulsed with one of the biggest wars that it has ever been its misfortune to experience. I do not know why, but it seems that from the earliest dawn of time, the comets have been looked upon with unfavorable eye. At the last appearance of Halley's comet, a long list of calamities that have occurred at each of its appearances was published. But calamities have occurred without the presence of a comet, and peace and prosperity have reigned supreme in spite of the presence of a comet.

Be it as it may the comet in question otherwise unimportant, gained notoriety owing to the present war. It was discovered by M. Delavan at La Plata on the 17th of December 1913, and since then it has been continuously visible at one portion of the globe or other up to the month of October. Although very faint at first it began to increase in brilliancy as it approached perihelion point. The comet was moving very slowly, about 12 or 13 miles per sec., which gradually increasing became about 26 miles per sec.* at perihelion. As the comet was moving so slowly it was expected that it would afford ample opportunity for its orbit to be determined accurately. But curiously enough the job was not so easy as it was thought at first. The first to venture to predict its orbit was Prof. Kobald of Germany. From the elements he could gather from observations of three consecutive nights, but when it was so slow as to render calculations almost uncertain he gave out the orbit to be a parabola with the perihelion to occur about the 2nd March 1914. A few days' observation convinced him that the calculation was greatly in error. He then gave out a second calculation that made the perihelion occur about the 14th October 1914. Another Astronomer Mr. Goudy calculated the orbit to be elliptical with a period of about 5,932 years. Then Dr. Crommelin took upon himself the task of calculating the orbit. Owing to the hazy condition of the atmosphere he could not make the necessary observations himself, but at his request Revd. T. E. R. Phillips was successful in obtaining an observation on January 22nd. With this and two other observations, one made on December 18th and the other on December 29th, he calculated the path to be a parabola with the perihelion about the 26th October. This calculation was in agreement with those by Messrs. Einarsson and Nicholson of the Lick Observatory and Dr. Biesbrock. I mention all these here to show how difficult it is to calculate the orbit of a comet. The slide (No. 1) here will show you the positions of the Earth and the comet in their respective orbits.

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* This has been obtained from a formula given by Dr. Crommelin in the February No. of B. A. Association's Journal :—

The speed of the Earth is 18·48 miles per sec. The log of this =1·2668. Adding this to the log of $\sqrt{2}$ or 0·1505 we obtain 1·4173 the log of the parabolic speed in miles per sec. at distance 1 from the Sun. The log of the parabolic speed at any other distance is obtained by subtracting $\frac{1}{2}\log r$ from 1·4173—Log r for October 26 is given to be equal to 0·0438. Subtracting $\frac{1}{2}$ of ·0438 from 1·4173 we get 1·3954.

Now the log of 1·4173=26·14
and the log of 1·3954=24·85

adding we get 50·99 or say 51

$\frac{1}{2}$ of 51, *i.e.*, 25·5 or about 26 miles per sec. is the mean speed.

I first saw the comet on the morning of the 30th September at a place just a little to the east of 65 Ursa Major. It appears to be a very small object not as bright as could be expected from a comet so near the perihelion. Dr. Crommelin in a paper communicated to the British Astronomical Association predicted that this comet which at discovery was only of about 10½ mag. would increase to about a thousand mag. (or a hundred times brighter than a star of 1st mag.), when near the perihelion and expressed his confidence that it would be readily visible to the naked eye and might really prove a grand object. As I found it, it was a very poor naked eye object, faint, hazy and streaky, and had I not known that there was a comet there I am sure I could not have found it out. But this may have been due to the haziness of the atmosphere.* The tail, as far as I could judge, was about 2° in length. But the position I found it in agreed will with the position assigned to it for that date by Dr. Crommelin (Slide No. 2). The comet was then moving towards α Canes Venatici. I saw it again on the 4th of October, but owing to the clouds could not determine its position. Slide No. 3 is the photograph of the comet taken by Dr. Bohlin of the Stockholm Observatory. It shows two distinct tails ; the one which is thrown more to the back is most probably composed of gaseous matters and the other of metallic vapour. I have not got the result of the spectroscopic analyses of the comet at hand or I could have given you the names of the elements that were found in the composition of the comet. The one thing peculiar about this comet and which was never known to occur in any other comet, was that it was seen 10 months before perihelion. Even Halley's comet was photographed only 8 months before perihelion. Slide No. 4 shows the comet as I saw it through a 2·4" refracting telescope with a power of about 50.

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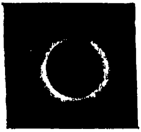
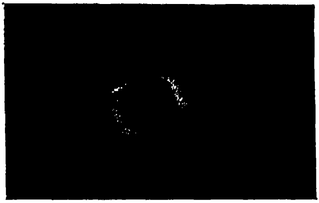
* In the Comptes Rendus for 28th September M. Puiseux of the Paris Observatory communicates that on September 5th and 6th the comet was a little fainter than a 3·3 mag. star. In the same number of Comptes Rendus M. Coggia gives five observations of positions of this comet made between September 14th and 18th. On these dates the comet presented a nucleus of about mag. 5 with a tail of about 1° in length. So it will be readily seen that the comet was actually diminishing in brilliancy as it was approaching perihelion.



No. 5.

ECLIPSE, August 21st, 1914.



No. 7.

ECLIPSE, August 21st, 1914.

Note on the Total Eclipse of the Sun of August 1914.

NOTE BY R. C. SLATER, ESQ., F.R.A.S.

I AM enclosing two lantern slides of the Corona. I took the photographs at Strömsund, Sweden, No. 5 with an exposure of ½ sec. and No. 7 with 2½ sec. on Isolar plates. These are slow plates, but they show a fair amount of Corona. On No. 7 you can pick out Regulus with a magnifying glass E. of the Sun. I unfortunately sent my instruments to Riga, but the outbreak of the war prevented my getting there, and as I only had the lens with me the rest of the apparatus I had to make after arriving at Strömsund with a minimum of tools and from very soft green wood. I had to focus 2 or 3 days before the eclipse, and the wood warped so that the focus is not good. The lens was 4″ in diameter, but of poor quality, and as I had no means of following the Sun, and no slow motions, I am surprised that the definition is as good as it is. I took altogether 4 photographs with this lens, and 4 with an ordinary camera I had with me. The latter are on a very small scale, but show some details, and would have been sufficient to demonstrate the type of the Corona if no others had been available.

The weather conditions on the day were excellent, but on every other day that we were there the sky was overcast at eclipse time.

If you think these would be of any interest to the Astronomical Society of India I shall be very pleased if you will make use of them.

NOTE BY H. G. TOMKINS, ESQ., C.I.E., F.R.A.S.

I HAVE been so fortunate as to obtain for the Astronomical Society of India two views of this eclipse taken by Mr. R. C. Slater, F.R.A.S., who was one of the few fortunate observers to see the eclipse. Mr. Slater has most kindly sent me two slides for the Society in India as well as a very interesting letter showing when and how they were taken.

The eclipse was total for about 2 minutes more or less according to the place of observation. The line of totality ran through Norway and Sweden, across the Baltic, Russia to the Black Sea, and thence across Persia to the coast upon the Indian Ocean to a point just west of Guzerat (India). India, therefore, just missed being on the line of totality. Elaborate preparations were made by scientists all over the world to view the eclipse and points on the line of totality were selected all along the line from Norway to the Black Sea. Most of the parties had started on their journeys to these stations and their instruments were on the way when a difficulty, which they certainly had not calculated on, occurred. War broke out on the 4th August 1914 just 17 days before the eclipse. The risk of bad weather had been carefully examined and allowed for by choosing the best places available. The unexpected happened, and just as every-one was on the move to their stations for observation, the mobilization began and caught the scientists in its meshes. Several of the English Astronomers, who were soldiers, had their thoughts transferred by telegram from science to war, and went Home again to duty by the shortest routes. Others whose presence was not so necessary in England or their own countries, stayed on. The German party, if report says true, were taken prisoners by the Russians and their instruments confiscated! War put an almost complete stop to many of the observations. We are therefore extremely fortunate in having obtained the slides, so kindly given us by Mr. Slater as well as his letter. Although he did not get his instruments for use at the eclipse, he was not altogether denied the object of his visit to Sweden, and he was probably rather glad he had selected that country to go to for the purpose. Some oft he parties in Russia were successful and an interesting account of the one at Minsk will be found in the *Observatory* for October 1914.

The Corona was of the intermediate type—that is to say there were no long streamers. The Corona was very bright. No shadow bands appear to have been seen.

I attach Mr. Slater's letter which give interesting details of his observations.

The Nebulæ and their Relation to Cosmic Evolution.

BY THE REVD. A. C. RIDSDALE, M.A., F.R.A.S., F.R. MET. SOC., M. LOND. MATH. S., F.PH.S., A.L.C.M., FOREIGN MEMBER OF SOCIETE ASTRONOMIQUE DE FRANCE.

THE Nebulæ are masses of shining diffused matter, shreds and balls of cloudy stuff distributed here and there throughout the immensities of space. The most notable of the Astronomers who have given special attention to the discovery and study of these celestial objects are Messier, the two

Herschels, Lord Rosse, the Bonds and the brothers Struve. Under insufficient telescopic power it is impossible to distinguish between a nebula and a star cluster, because the individual stars of a star cluster cannot then be separated. The Cluster Præsæpe to the naked eye looks exactly as if it were a nebula, although a very small telescopic power will reveal individual separate stars. Herschel showed with his large telescopes that many objects which had hitherto been taken for nebulæ were really clusters of stars. It was erroneously thought that all nebulæ could probably be resolved into star clusters if the telescopic power were sufficiently great, and that there was no real difference between the two. It was even reported that Lord Rosse's telescope had resolved the Orion nebula. This was not true, for we now know that the Orion nebula is wholly gaseous. Speaking of nebulæ Lardner, writing in 1853, says : "There are star clusters, of which the component stars are indistinguishable only by reason of their remoteness." But the spectroscope has shown us that there are multitudes of nebulæ that are not star clusters at all, but immense masses of glowing gas. This important discovery was made by W. Huggins in 1864. It is not unlikely, however, that nebulæ and star clusters shade into each other as it were by insensible gradations. The first historical record we possess of the discovery and recognition of such a thing is in Huygens' "Systema Saturnium." Writing in 1659 he says : "There is one phenomenon among the fixed stars worthy of mention, which, as I believe, hath hitherto been noticed by no man, and indeed cannot well be observed but with large telescopes. In the sword of Orion seven stars shone through a nebula, or small bright cloud, such that the space around them seemed far brighter than the rest of the heavens ; so that it appeared as an opening in the sky, through which could be glimpsed the glory of the empyrean." A great advance in our knowledge the nebulæ has been achieved by the invention of the photographic dry plate. The first photograph of a nebula was produced by Dr. Draper in 1880. Eye observations and drawings cannot at all compete with the photograph. The photograph has revealed important and essential features of nebulæ never recognized before by the largest telescopes, as for example the concentric rings of the Andromeda nebula, which so greatly resemble the rings of Saturn. With the visual telescope very little of the nebula can be seen at the same time, since the field of an eyepiece is very small. Thus in the case of Andromeda visible even to the naked eye, drawings left us in ignorance of this very essential feature, namely that the dark rifts are curved and not straight, a fact which makes all the difference in estimating their meaning. Photography moreover captures objects which are far too faint to be seen by the eye, and the sensitive plate never tires like the eye, but will receive more and more impressions the longer the exposure. A very faint, dim light with long exposure will give as clear an impression as a brighter light with shorter exposure. The photograph however does not give the relative brightnesses accurately, since the exposure necessary to bring out faint details is far too great for the brighter parts. However this defect can be mostly remedied by taking several negatives of different length of exposures. There are about 10,000 nebulæ already catalogued. Herschel was the first to go systematically into the question of the nature and number of the nebulæ. Since his time Huggins has been the greatest discoverer by means of the spectroscope. He proved thereby that the light of true nebulæ proceeds from luminous gas. They give a spectrum of six or seven bright lines, namely F Hydrogen, HJ Hydrogen, H Hydrogen, D2 Helium and another Helium and two other unknown and unidentified lines, called provisionally "Nebulium." Lockyer thought it indicated the presence of magnesium, but this was an error. All gaseous nebulæ give this same spectrum, except that if too faint, only the brighter lines appear. Photography of late has proved very useful in the study of nebular spectra. By its means we now have a list of as many as 70 lines photographed in the spectra of gaseous nebulæ. 55 lines have been detected in the Orion nebula alone. The nebulæ do not all give a gaseous spectrum. Those that do so are all of the same greenish tint. The white nebulæ, such as Andromeda, give a perfectly continuous rainbow spectrum with no lines. This means that the white nebulæ are either composed of gases under high pressure, or of solids or liquids heated to incandescence. They are probably composed of partially cooled matter. Like the green nebulæ however they withstand all attempt at resolution into star clusters. Photography with an ordinary portrait lens at the focus of the telescope has revealed the fact that vast regions of the sky are veiled in faint, diffused nebulous matter. These delicate veils are invisible to the eye even through the best telescopes. It has been conjectured that possibly with long enough exposure, the whole sky might prove to be veiled over with nebulosity. The distribution of the nebulæ is not uniform over the sky. They are wholly absent from some regions, and crowded in great profusion in others. Thus there is a cluster of nebulæ in Coma Berenicis, and more than a hundred nebulæ are crammed here into a space less than that occupied by the Full

Moon, or 31 minutes diameter. They seem to avoid the Galaxy and have a preference for the galactic poles. Their tendency is to avoid the regions where stars abound. There seems to be some "relation of contrariety" between the nebulæ and the stars. Perhaps the stars devour them, appropriating the surrounding nebulosity. W. Herschel made an extensive survey of the northern hemisphere, and his son, J. Herschel, at the Cape Observatory of the southern, and between them catalogued 4,000 nebulæ. J. Herschel says nearly a third of all the nebulæ are congregated in an irregular patch which stretches from Ursa Major to Virgo. Since then Dreyer has catalogued 10,000, and Keeler estimates there are 120,000 nebulæ within reach of the Crossley reflector. Cleveland Abbe has shown that in a belt of 30 degrees wide including the milky way, which means three quarters of the celestial globe, only one-tenth of the number of the nebulæ are found within this belt. Up to the present time no parallax has yet been discovered for any of the nebulæ, nor is it likely that their distances will ever be found by this method. Being, indeed, of so indefinite and hazy an outline it would be very difficult to measure any parallactic displacement with the micrometer. And yet they are so associated with stars that it is impossible to doubt that they are at the same order of distance. For example in the Pleiades, star is connected with star by wisps of nebulosity. The longer the exposure, the more nebulosity is revealed amongst the stars of the Pleiades, each star having its own nebulous veil more brilliant than the region between the stars, whilst the entire group is bound together in a vast net of nebulosity, extending far out on all sides into space. When our Sun is eclipsed, we then see his nebulous envelope which we call his Corona. The stars of the Pleiades also have their Coronæ only on a vastly larger scale than the Sun's Corona. Again in the Orion nebula, four groups of lines in the spectrum of the nebula coincide with corresponding lines in the spectrum of the neighbouring stars, which makes it probable that the stars are of the same composition as th nebula and lie within it. And again the dark space, in which the stars of the Trapezium lie, points to the fact that the nebulous matter in their proximity had been used up as it were in forming them. If it is true that any nebula and its adjacent stars are at the same distance, then it would be possible to find the distance of the nebula so long as a parallax for the star could be found. As yet no parallax for any nebulous star has been found. The spectroscope has shown that the radial motions of nebulæ are of the same order as those of the stars. In 1890 Keeler carefully observed many of the nebulæ in order to discover radial motion with a spectroscope of high dispersive power. He found that, like star motion, their motions away and towards us ranged from zero up to 40 miles per second. No motion in rotation has yet been visually observed, although it is certain that nebulæ must possess such a motion. The velocity of rotation of any system varies inversely as the square root of its moment of inertia, and therefore also of its density. Hence a very light and large mass would have a very slow rotation. And, further, according to the laws of dynamics, the inner particles in order to preserve their equilibrium will have to rotate more rapidly than the outer. Hence the distinct spiral or whirling appearance of most of the nebulæ. Again, the gravitation towards the axis of rotation varies as the distance. And centrifugal force also varies as the distance, whatever the velocity. Hence a whole sphere may rotate in accordance with these laws, so that no change in the relative distances of the particles will disturb the equilibrium. Again, the expansiveness of gases varies inversely as the space in which they are confined. This would account for the particles not falling into the equatorial plane. Again, the expansiveness of gases varies inversely as their volume. Thus as the radius increases, the expansiveness would diminish inversely as the cube of the radius, whereas the attraction would only diminish as its square. Hence there is a definite bounding-surface to a nebula. Nebulæ are of very varied character and forms. There are Annular, Ring, Planetary and Spiral, and Irregular nebulæ. Most nebulæ, however, have a more or less marked condensation at the centre thinning off towards the extremities. The largest nebulæ are the irregular ones, such as Orion, which is now known from photographs of long exposure to include nearly the whole area occupied by the constellation. It seems probable that certain changes in the form of some of the nebulæ have been detected from the comparison of drawings made at different dates. Especially is this the case with Eta Argus, and the "trifid" nebula in Sagittarius, and the Omega nebula. The nebula in Sagittarius has near its centre a curious dark rift. In the middle of this rift Herschel says the triple star was placed, which is now placed not in the middle but at the confines of the nebula. The star has not moved relatively to the neighbouring stars, and therefore it is concluded that the nebula must have changed its form and position. Again, in the case of the Omega nebula, it certainly does not any longer retain any resemblance to that letter. Professor Holden thinks that although the shapes of nebulæ suffer little or no change, the relative brightnesses of their parts are continually, though gradully changing. Too great reliance however must not be placed upon the evidence we have in favour of change in the nebulæ. The evidence rests chiefly upon mere eye drawings of the nebulæ, and it is notorious how very differently two men will delineate the same nebula at the same time. They are exceedingly hazy and indefinite objects to make eye drawings of, and the question of change cannot be settled until not drawings but photographs shall have been composed and discussed for a period of many years to come. It is certain, however, that some nebulæ vary in brightness. Epsilon Tauri is a good example of a variable nebula. It can sometimes be seen with quite a small telescope, and at others not with the largest. The change seems to have no regular periodicity. The larger and brighter and more irregular of the nebulæ generally stretch out streamers on all sides, and contain dark rifts or "lanes," such as the "fish-mouth" of Orion, and the circular rifts of Andromeda. The enormous size of some of the nebulæ may be roughly estimated from comparisons of their angular measurements with the apparent distance of Neptune from the Sun as seen from Alpha Centauri, the nearest star. The diameter of Neptune's orbit would appear to be only one minute of arc as seen from Alpha Centauri. The angular diameter of the Orion nebula as seen from the earth is several degrees. And it is certain the nebula is vastly further away from us than is Alpha Centauri. Therefore the central portion alone of the Orion nebula must occupy a space at least many thousands of times greater than the orbit of Neptune, whose radius is thirty times greater than the 93,000,000 miles radius of the Earth's orbit. If our Sun were enveloped in such a nebula, its tentacles would reach out to Polaris which is forty-four light years' distant. It is probable that the thickness or depth of the Orion nebula is not so great as its breadth or visible extension. The next largest nebula is in Andromeda. It is often mistaken for a comet by the uninitiated. It is a very long oval 2½ degrees of arc in length, and over a degree in breadth. It is sown over with multitudes of stars, 200 of which are found within 20 minutes of diameter. It is one of the regular or spiral nebulæ. It appears to be an enormously magnified edition of the Saturnian system, except that the nucleus is not globular, but merges into the rings. Its thickness or depth must be hundreds of millions of miles, and yet we can see through it. The smaller nebulæ are more regular and generally elliptical and almost circular in shape. The most regular in shape are called "planetary" nebulæ from their close resemblance to planetary disks; most of them are in the southern hemisphere. In some cases the disk shows a uniform surface, in others what Herschel calls a "mottled" or "curdled" appearance. These planetary nebulæ are of various colours or tints, of great beauty. Others are very elongated ellipses with every variety of eccentricity, others hardly more than slender wisps or streaks of light, probably denoting that they are seen edgewise. They generally are condensed towards the centre and often have a star at the centre of the condensation. The true forms of these nebulæ are probably grobular. There are thousands of "nebulous stars," or stars surrounded by an envelope of nebulous mist. There are a comparatively few nebulæ which are not condensed in the centre, but on the contrary are dark or nearly dark in the centre and brighter at the circumference. Only a few dozen have so far been discovered. These are the Annular or Ring nebulæ, such as the famous nebula between Beta and Gamma Lyræ. Such nebulæ are probably of a flat disk shape. There are also double nebulæ, suggesting the idea of double stars in the making. It is almost certain that such clusters of nebulæ must be physically connected, and it is very probable that they move round each other or rather round their common centre of gravity like binary stars. Their apparent motion owing to their immense distance and comparatively low density is so slow that it could not be visually detected probably for thousands of years. But the most universal and characteristic form of nebula is the Spiral nebula. These were first discovered by Lord Rosse. They have the form of a mop when it is being wrung out, with curved arms issuing from a central condensed nucleus, presenting the appearance of rapid rotation about the nucleus as centre. The Spiral nebula is hence often called the whirlpool form of nebula. The forms of nebulæ appear to vary greatly with different telescopic powers, just as small objects change in appearance when seen under a microscope, from what they appeared as seen by the naked eye. Thus what used to be considered a double nebula and was called the Dumb-bell nebula has now been by larger telescopic power shown to be of the spiral form. The apparent form, it must be remembered, of any object in the heavens is that of a cross section of the real form, made by a plane at right angles to the line of vision. If the mass had a rotational motion such as the planets have, their exact form could then be mathematically deduced. But the nebulæ present no such rotational motion, and therefore their true shape can only be guessed from their structural appearance. The intrinsic light of nebulæ must be vastly less than that of the Sun. For if the Sun subtended an arc in diameter of only 1 minute, its light would at that distance yet exceed that of 750 Full Moons, whereas the nebulæ which in many cases have an arc of diameter much greater than 1 minute cannot even be seen at all with the naked eye. Arago propounded the view that nebulæ shone with reflected light from stars hidden away in their centres, but this somewhat fantastic view is now quite discredited. It is certain they shine by their own intrinsic brightness, they are luminous gases of the most elemental type, less dense than any vacuum that could be produced on Earth. It is, indeed, a mystery how such tenuous objects can assume and retain such clear and sharp outlines as they exhibit in their photographs. In most cases it looks as though the gas were in violent rotational motion, but how and when the force is impressed to produce such motion is an unsolved mystery. Much information regarding the connection of stars and nebulæ was afforded by the "new star" of 1901 in Perseus. In February there seemed to be no nebulosity in connection with the star, but in September a photograph revealed two wisps of nebulosity extending from the star. In November the Spiral nebula around the star seemed to have extended outwards, at a rate of 11 minutes of arc in a year. Now the question is, did the nebulous matter really travel out from the star at that rate, or was the phenomenon not rather due to the light from the outbursting central star travelling towards the edges of the nebula that was already there? The latter seems to be far the more probable hypothesis of the two. If so, it means that light took one year to travel over the eleven minutes of arc as seen from our distance, and consequently judging from the velocity of light, the new star and nebula in Perseus would be distant from us three hundred light years. The outburst must then have actually occurred just when Galileo first directed his "optic tube" towards the heavens, the news of which has only reached us in 1901. The inference can also be drawn that the nebula that was thus gradually lighted up must be 26 millions of millions of miles in circumference, or over eight millions of millions of miles in diameter.

A treatise on nebulæ would be incomplete if no mention were made of the connection between nebulæ and the important theory of the origin and evolution of the Universe known as the "Nebular hypothesis." The study of such a nebula as that of Andromeda and the knowledge lately gained regarding its formation seems to strongly corroborate and confirm the truth of the nebular hypothesis. Here we have a central nebula, which seems to have thrown off rings in rotation, some of the substance of which seems to have already conglomerated into rudimentary satellites. These are two distinctly formed and others seem to be in course of formation. Such a general evolution not only for the solar system but for the whole Universe was already thought out by Laplace, over a century before the true formation of the Andromeda and other Spiral nebulæ were even guessed at. The evidence of the modern photograph has illustrated Laplace's theories as facts, much in the same way as the theories of Copernicus regarding planets and satellites were confirmed when Galileo invented his optic tube and actually saw real satellites circulating around Jupiter. Thus the new knowledge we have gained of the nature of the nebulæ, throws a flood of new light on the historical development or evolution of the Universe. The "Nebular hypothesis" was first suggested by the philosopher Kant, but developed and treated in a more vigorously mathematical and scientific manner, as we have said, by the great mathematician Laplace. The theory in spite of modification in detail is still held in the main just as Laplace propounded it. Laplace confined his enquiries chiefly to the origin of the solar system, but the same theory may be extended on a magnified scale to the stellar Universe. According to his theory, the Solar nebula was originally a mass of heated gas. We now believe it was a cloud of cold dust. It can be mathematically shown that the mutual attractions of its particles would cause the nebula to assume a globular form, to start rotating, and to begin to grow hotter. The laws of dynamics tell us that as it contracted, it began to rotate more rapidly, its poles began to get flattened and its equator to bulge out. Finally the centrifugal force at the equator would overcome the centripetal force there, and a ring of nebulous matter would escape. Or as is now thought more probable, denser portions of matter at the equator would be left behind and become the origin of satellites. As the original body still further contracted other rings or globular masses were liberated. These liberated masses would in their turn behave in like manner as the parent nebular mass, and throw off rings or balls of matter as they condensed, and consequently their rotation and centrifugal force became greater. Thus satellites to the planets would be formed. If the ring were of fairly homogeneous density, they might condense into an immense number of small bodies like the asteroids, or the lumps no larger than brick-bats which make up Saturn's rings. The planets and satellites must first have liquified, and then as they grew still cooler, solidified. Small bodies like the asteroids and satellites quickly lost their heat and are now probably solid throughout. The next larger sized bodies, such as our Earth, Venus, etc., formed a cooler crust whilst retaining in their centre matter at a high temperature. The largest planets, such as Jupiter and Saturn, have still retained their original nebular heat to such an extent that a cool crust has not yet been formed, and they are still in the semi-liquid stage. The huge central nucleus of the original nebula, the Sun, which has retained the vast majority of the primitive mass within himself, will not lose any appreciable heat until he begins to liquify. It used to be thought, when it was first discovered, that the satellites of Uranus and Neptune have a retrograde motion, and that the inner satellite of mass has a shorter period of rotation than its primary, that these facts strongly militated against the acceptance of the "nebular theory." It has now been proved mathematically that they present no real contradiction to the theory. Let us now see what help we can derive from our study of the nebulæ, in solving the riddle of cosmic evolution. Let us see the mutual relation existing between the various orders of bodies in the Universe, tracing the series from the nebulæ through the stars, down to our own solar system. Herschel very aptly compared the denizens of the sky to the trees of a forest, where can be seen plants in every stage of development, from the seedling to the prostrate trunks of the dead and faded old oak. In the heavens in like manner we can see objects in their infancy and in their old age. We have just recounted the theory of the nebular origin and evolution of the solar system as first propounded by Laplace and later improved upon by succeeding generations of Astronomers. Let us now extend our enquiries to the whole stellar Universe as known to us. In the first place, we find vast inchoate masses of elemental or primeval matter scattered in all directions throughout the Universe. Some of the vastest of these nebulæ can only be detected by photography, being too faint to be seen by the eye in the most powerful telescope. Surely, then, we are right in assuming this to be the raw material demanded by nebular evolution theory. Surely, this is the "world-stuff" of the philosophers in its most elementary form. Next look at the great Andromeda nebula. It presents as it were in a living picture the very epitome or summary of the nebular theory. Here we have the central condensing nucleus, the rings of tenuous matter thrown off as the nucleus rotates, and at least two very clearly defined condensed masses beginning to form themselves into dependent globes. Again, if we study the stars in the Trapezium of Orion, we see they are surrounded by a dark space eaten out of the surrounding nebulosity, which has been absorbed in their formation. If we examine the spectra of those Trapezium stars we see that it exactly tallies with the spectrum of the surrounding nebula. If we study the planetary nebulæ, we find we can arrange them in an orderly series from those which have only a slight central condensation, through those which exhibit a very clearly defined central nucleus, up to those which may properly be called nebulous stars, rather than planetary nebulæ, the process of solar system formation having been completely accomplished, the nebulosity around the star being the equivalent of our Sun's so-called Corona. Again, if we turn to the Phiades, we find every individual star involved in very distinct nebulosity, and star joined to star by rays of nebulous matter, and when the exposure of the photograph has been sufficiently long, we are amazed to find the whole group buried entirely in one vast nebula, whose dimensions utterly stagger the imagination. Here, then, again we find the closest connection between nebulæ and stars. Again, there are thousands of stars which appear to be enclosed in nebula, and the truth of this is confirmed by their very complicated spectra, as of incandescent solid bodies shining through gáseous envelopes. In fact the stars can be arranged in an orderly series of the spectra, beginning from the least developed planetary nebulæ right up to the most finished star. Turn to our own Earth. The volcano tells us the interior is exceeding hot, the thermometer carried below the surface tells the same tale. The geologist tells us that the granite of our mountains has been scorched by primæval fires, and that marble is but lime-stone transformed by intense heat. The mountains themselves are but the wrinkles of the Earth's contracted crust. Surely if the Earth were heated to incandescense it would give a spectrum similar to that of the stars. If we again turn to the solar system, we find that it is no mere accidental aggregation of bodies. Masses coming haphazard towards the Sun, would move as comets in every degree of inclination and eccentricity, but it is quite otherwise as regards the planets. We know, according to the nebular theory, the outer planets should have been formed from large rings of small density, and the inner rings from small rings of great density. Consequently the outer planets should be large but light and the inner planets small but heavy. And is not this true to fact? Then, again, in strict accordance with the laws of the nebular theory, the planets all rotate in the same direction as the Sun rotates, all nearly in the same plane, and that plane very nearly identical with the plane of the Sun's equator. The satellites also revolve in the plane of the equators of their respective primaries; which (with two exceptions which can be quite satisfactorily accounted for) are themselves again nearly in the plane of the Sun's equator. Again, if we turn to the Sun, we know that his heat is kept up by continual contraction. In other words he is growing smaller and smaller. Hence in past ages he was much larger than he is now. If we go back in our imagination over immense abysses of past time we see the Sun and his planets as one immense diffuse globular nebula, resembling in every detail the forms of nebulæ which we can, with the aid of powerful instruments, now see as at present existing in the Universe. As regards, however, the vast question of cosmic evolution itself, whilst astronomical science has indeed given us not a few clear and decided answers, there is a vastly greater number of important questions which by means of patient and earnest investigations yet remain to be solved, and other questions regarding this unspeakably immense work of the Creator which are, and always will be, infinitely beyond the capacities of man's finite and somewhat feeble intellect ever to solve. The range of man's powers of research may be likened to that of ephemeral insects, the series of processes which it is in the power of man to watch and to trace back may be likened to the series of events which take place within the limits of one day, which in the case of many insects represents a lifetime. All that can be said with any certainty regarding this cosmic evolution is that a universal process of condensation and aggregation of rarefied masses of matter (such as are the nebulæ) is now going on in obedience to certain dynamical laws of force, that the potential "energy of position" is throughout the Universe being converted into heat, that this generated heat is being in all directions radiated as energy into space, and to surrounding bodies as waves of light and heat, and that, if God does not hereafter decree otherwise, this process will continue until the temperature of all things in this Universe will have been reduced to absolute uniformity and hence to eternal death and stagnation. But further than this it is not in man's power to fathom even as regards merely this part of God's realm which we call the Universe. "Lo! these are but a portion of His ways, they utter but a whisper of His glory." We will conclude in the words of the old German seer : "God called a man into the vestibule of heaven. And to an angel He said : 'Take him, and strip from him his robes of flesh, cleanse his vision, and put a new breath in his nostrils, only touch not with any change his human heart.' It was done, and with a mighty angel for his guide the man stood ready for his infinite voyage. And from the terraces of heaven, without sound or farewell, at once they wheeled away into endless space. With solemn flight of angel's wings, they passed through zaharas of darkness, through wildernesses of death, that divided the worlds of life, over frontiers which were quickening under prophetic motions from God. Then from a distance which is counted only in heaven, light dawned from a shapeless film. With unutterable swiftness they swept to the light. In a moment the rushing of planets was upon them, in a moment the blazing of Sun was around them. Then came eternities of twilight. Then came mighty constellations built up like triumphal gates, resting by spans that seemed ghostly from infinitude. Without measure or number were the architraves. Within were stairs that scaled the eternities around. Above was as below, below as above, depth was swallowed up in height unsurmountable, height was swallowed up in depth unfathomable. Then the man sighed, and shuddered, and wept, and said thus to the angel: 'O Angel, I will go no farther, for the spirit of man acheth with this infinity. Insufferable is God's glory. Let me lie down and die, and hide me from the persecution of the Infinite, for end I see there is none.'"

The Proper Motion of Sirius.

BY R. J. POCOCK, ESQ., B.A., B.SC., F.R.A.S.

Sirius.—The brightest star in the sky—lies within the zones allotted to the Nizamiah Observatory, Hyderabad, for the Astrographic Catalogue.

Plate No. 396 was exposed on 1914 December 21 (=1914·969) with centre at approximately R.A. $6^h\ 44^m$, Decln. -17°; exposures 15 min. and 8 min.

On this plate Sirius is near the edge and consequently considerably out of focus, the images consisting in a dark ring or halo within which is a dark circular disc with bright centre. The inner edge of the halo is clearly defined its diameter being about $6'\cdot15''$ the outer edge shades off too imperceptibly to be accurately measured. The halos and dark discs formed by the two exposures overlap but the central white spots are separated and easily measureable. The symmetry of the halos and discs afford evidence that the object glass of the 8-inch telescope with which the plate was taken is sensibly free from tilt.

The position of the star (for 1900·0) given in the Washington A. G. Catalogue is—

R. A. $6^h\ 40^m\ 45^s\ \cdot56$ Decln. $16^\circ\ 34'\ 44''$ O. S.
or in "Standard Co-ordinates" referred to the above plate centre

$$\xi' = 3\cdot6354 \qquad \eta' = 7\cdot9657$$

while those obtained from the plate are

$$\xi' = 3\cdot5996 \qquad \eta' = 8\cdot0270$$

the difference $\Delta\xi' = -\cdot0358$ $\Delta\eta' = +\cdot0613$ is due to Proper Motion.

These differences are equivalent to —0·716 secs. and —18″ ·39 in R.A. and Decln. respectively.

Taking the Proper Motion and Orbital Motion from the Nautical Almanac we find

	R.A.		Decln.
Proper Motion	—·558	secs.	—18·07
Orbital Motion	—·140		— 0·32 (for 1915·0)
	—·698		—18·39

as compared with —·716 secs. —18″·39 obtained above : the difference is less than the unit of measurement.

The total number of stars measured on the plate is 477, which is 3·9 times the number in the corresponding region of Schonfeld's Map.

Memoranda for Observers.

Standard Time of India is adopted in these Memoranda.

For the month of April 1915.

Sidereal time at 8 p.m.

	H.	M.	S.
April 1st	8	35	28
,, *8th*	9	3	4
,, *15th*	9	30	40
,, *22nd*	9	58	16
,, *29th*	10	25	52

From this table the constellations visible in India during the evenings in April can be ascertained by a reference to a Star Chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian

The Moon.

PHASES—

April	*7th*	at	1-42 A.M.	Last quarter.
,,	*14th*	,,	5- 5 P.M.	New Moon.
,,	*22nd*	,,	9- 9 ,,	First quarter.
,,	*29th*	,,	7-49 ,,	Full Moon.

OCCULTATIONS—

April	*4th*	at	10-42 A.M.	Antares	Between	0°	and	73° S.
,,	*9th*	,,	5-30 ,,	Uranus	,,	20° N.	,,	62° S.
,,	*17th*	,,	4-30 P.M.	The Pleiades	,,	90° N.	,,	38° N.
,,	*25th*	,,	12-34 A.M.	Regulus	,,	12° S.	,,	78° S.

CONJUNCTIONS—

April	*11th*	at	8-37 A.M.	with Venus	(Planet	2°-36′	South.)
,,	*11th*	,,	5-39 P.M.	,, Jupiter	,,	3°- 6′	,,
,,	*12th*	,,	3-34 ,,	,, Mars	,,	4°-12′	,,
,,	*13th*	,,	7-19 A.M.	,, Mercury	,,	6°-14′	,,
,,	*20th*	,,	2-53 ,,	,, Saturn	,,	5°- 0′	,,

The Planets.

The planets are all morning stars except Saturn and Neptune. At the beginning of the month, Mercury, Mars and Jupiter are all close together near the eastern boundary of Aquarius, rising a little more than an hour before the Sun, and preceded by Venus who rises in the same constellation about an hour earlier. Venus will be in conjunction with Jupiter on the 15th when only nine minutes of arc will separate the two planets.

Mars.—Position on the 15th R. A. 23·57 Dec. 1°-24′ S. in Pisces.

Jupiter.—Position on the 15th R. A. 23·11 Dec. 6°-13′ S. in Aquarius.

Saturn.—Position on the 15th R. A. 5·48 Dec. 22°-37′ N. in Taurus.

Uranus.—Position on the 15th R. A. 21·11 Dec. 16°-54′ S. in Aquarius.

Neptune.—Position on the 15th R. A. 7·58 Dec. 20°-17′ N. in Cancer.

For the month of May 1915.

Sidereal time at 8 p.m.

	H.	M.	S.
May 1st	10	33	45
,, *8th*	11	1	20
,, *15th*	11	38	56
,, *22nd*	11	56	32
,, *29th*	12	24	8

From this table the constellations visible in India during the evenings in May can be ascertained by a reference to a Star Chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

The Moon.

PHASES—

May	*6th*	at 10-52 A.M.	Last quarter.
,,	*14th*	,, 9- 1 ,,	New Moon.
,,	*22nd*	,, 10-20 ,,	First quarter.
,,	*29th*	,, 3- 2 ,,	Full Moon.

OCCULTATIONS—

May	*1st*	at 7-45 P.M.	Antares	Between 8° N. and 61° S.
,,	*6th*	,, 12- 8 ,,	Uranus	,, 38° N. ,, 42° S.
,,	*16th*	,, 7-46 ,,	Nath	,, 34° S. ,, 62° S.
,,	*22nd*	,, 8-36 A.M.	Regulus	,, 40° S. ,, 78° S.
,,	*29th*	,, 6- 6 ,,	Antares	,, 11° N. ,, 58° S.

CONJUNCTIONS—

May	*9th*	at 10-38 A.M.	with Jupiter	(Planet 3°-53′ S.)
,,	*11th*	,, 3-27 P.M.	,, Venus	,, 6°-28′ S.
,,	*12th*	,, 6-25 ,,	,, Mars	,, 5°-38′ S.
,,	*15th*	,, 7-46 ,,	,, Mercury	,, 2°-51′ S.
,,	*17th*	,, 2-30 ,,	,, Saturn	,, 4°-36′ S.

The Planets.

Mercury—Is in superior conjunction with the Sun at 11-30 P.M. on the 1st and then becomes an evening star. From the middle of the month he will set more than an hour later than the Sun, increasing his distance until the 31st, when he will set an hour and half later.

Venus—A morning star, rises in Pisces about two hours before the Sun on the 1st. She moves into Aries on the 18th.

Mars—Keeps close to Venus throughout the month, the two planets being in conjunction on the 14th, when Venus will be 0°-56′ to the South of Mars. Position on the 15th R. A. 1·22 Dec. 7°-43′ N.

Jupiter—Rises about three hours before the Sun on the 1st and about five hours before on the 31st. Position on the 15th R. A. 23·33 Dec. 4°-0′ S. in Pisces.

Saturn—An evening star, moves out of Taurus into Gemini during the 1st week of the month. Position on the 15th R. A. 6·1 Dec. 22°-43′ N.

Uranus.—Position on the 15th R. A. 21·13 Dec. 16°-47′ S. in Capricornus.

Neptune.—Position on the 15th R. A. 8·0 Dec. 20°-14′ N. in Cancer.

For the month of June 1915.

Sidereal time at 8 p.m.

		H.	M.	S.
June	*1st*	12	33	58
,,	*8th*	13	3	34
,,	*15th*	13	31	10
,,	*22nd*	13	58	45
,,	*29th*	14	26	21

From this table the constellations visible in India during the evenings in June can be ascertained by a reference to a Star Chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

The Moon.

PHASES—

June	*4th*	at	10- 2 P.M.	Last quarter.
,,	*13th*	,,	12-27 A.M.	New Moon.
,,	*20th*	,,	7-54 P.M.	First quarter.
,,	*27th*	,,	9-57 A.M.	Full Moon.

OCCULTATIONS—

June	*25th*	at	2-58 P.M.	Antares	Between 9° N. and 59′ S.
,,	*30th*	,,	4-59 A.M.	Uranus	,, 63° N. ,, 18′ S.

CONJUNCTIONS—

June	*6th*	at	1-38 A.M.	with Jupiter	(Planet 4°-38′ S.)
,,	*9th*	,,	7-25 P.M.	,, Mars	,, 6°- 1′ S.
,,	*10th*	,,	8-45 ,,	,, Venus	,, 6°-38′ S.
,,	*14th*	,,	2-52 A.M.	,, Saturn	,, 4°-16′ S.
,,	*14th*	,,	1-12 P.M.	,, Mercury	,, 4°-18′ S.

The Planets.

Mercury—An evening star, is at greatest elongation 23°-17′ East on the 1st and will be visible during the first half of the month as he sets about an hour and a half after the Sun on the 1st and nearly an hour after on the 15th. He will be in inferior conjunction with the Sun on the 27th, and will then become a morning star.

Venus—Is a morning star rising in Aries about an hour and three quarters before the Sun on the 1st. She moves into Taurus before the middle of the month and will be in conjunction with the Pleiades on the morning of the 14th.

Mars—A morning star, rises from two and a half to three hours before the Sun as the month advances. Position on the 15th R. A. 2·51 Dec. 15°-45′ N. in Aries.

Jupiter—Also a morning star, will be in quadrature with the Sun on the 19th rising then at about midnight. Position on the 15th R. A. 23·40 Dec. 2°-24′ S. in Pisces, to the south of the Great Square of Pegasus.

Saturn—An evening star, sets about an hour and a half after the Sun on the 1st, but will be in conjunction with the Sun on the 28th and then becomes a morning star. Position on the 15th R. A. 6·18 Dec. 22°-24′ N. in Gemini.

Uranus.—Position on the 15th R. A. 21·12 Dec. 16°-52′ S. in Capricornus.

Neptune.—Position on the 15th R. A. 8·3 Dec. 20°-5′ N. in Cancer.

The Sun

Attains its maximum declination north, and enters the sign of Cancer at 5·59 P.M. on the 22nd, being the summer solstice.

For the month of July 1915.

Sidereal time at 8 p.m.

	H.	M.	S.
July 1st	14	34	15
,, *8th*	15	1	51
,, *15th*	15	29	26
,, *22nd*	15	57	2
,, *29th*	16	24	38

From this table the constellations visible in India during the evenings in July can be ascertained by a reference to a Star Chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

The Moon.

PHASES—

July	*4th*	at	11-24	A.M.	Last quarter.
,,	*12th*	,,	3- 0	P.M.	New Moon.
,,	*20th*	,,	2-38	A.M.	First quarter.
,,	*26th*	,,	5-41	P.M.	Full Moon.

OCCULTATIONS—

July	*10th*	at	8- 3	A.M.	Nath	Between	35° S.	and	62° S.
,,	*23rd*	,,	1-47	,,	Antares	,,	4° N.	,,	65° S.
,,	*27th*	,,	1-32	P.M.	Uranus	,,	60° N.	,,	20° S.

CONJUNCTIONS—

July	*3rd*	at	2-13	P.M.	with	Jupiter	(Planet 5°-12′ S.)
,,	*8th*	,,	6-31	,,	,,	Mars	,, 5°-30′ S.
,,	*11th*	,,	1-43	A.M.	,,	Venus	,, 4°- 7′ S.
,,	*11th*	,,	2-22	,,	,,	Mercury	,, 7°-57′ S.
,,	*11th*	,,	4- 4	P.M.	,,	Saturn	,, 4°- 0′ S.
,,	*11th*	,,	11-31	,,	,,	Jupiter	,, 5°-29′ S.

The Moon will enter the Penumbra of the Earth, but not the Umbra, on the 26th at 5-30 P.M.

The Planets.

Mercury—Is now a morning star but too near to the Sun to be visible during the first week of the month. From then to the third week he may be visible, rising in Gemini a little more than an hour before the Sun.

Venus—Also a morning star, rises nearly an hour and a half before the Sun on the 1st in Taurus. She will move through Gemini during the month, and by the 31st she will rise less than an hour before the Sun.

Mars—A morning star, rises from three to three and a half hours before the Sun as the month advances. Position on the 15th R. A. 4·18 Dec. 21°-6′ N. in Taurus, between the Pleiades and Aldebaran.

Jupiter—Will rise at about half an hour before midnight on the 1st and at about 9-30 P.M. on the 31st. Position on the 15th R. A. 23·56 Dec. 1°-50′ S. in Pisces.

Saturn—Now a morning star, will be too near to the Sun to be visible until about the end of the month, when he will rise about two hours before the Sun. Position on the 15th R. A. 6·35 Dec. 22°-34′ N. in Gemini.

Uranus.—Position on the 15th R. A. 21·9 Dec. 17°-10′ S. in Capricornus.

Neptune.—Position on the 15th R. A. 8·7 Dec. 19°-52′ N. in Cancer.

The Sun

Will be in apogee at 3-30 A.M. on the 6th.

For the month of August 1915.

Sidereal time at 8 p.m.

	H.	M.	S.
August 1st	16	36	28
,, *8th*	17	4	4
,, *15th*	17	31	40
,, *22nd*	17	59	16

From this table the constellations visible in India during the evenings in August can be ascertained by a reference to a Star Chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

The Moon.

PHASES—

August	*3rd*	at	2-57	A.M.	Last quarter.
,,	*11th*	,,	4-22	,,	New Moon.
,,	*18th*	,,	7-47	,,	First quarter.
,,	*25th*	,,	3-10	,,	Full Moon.

OCCULTATIONS—

August	*6th*	at	3-17	P.M.	Nath	Between	28° S.	and	62° S.
,,	*19th*	,,	8-21	A.M.	Antares	,,	3° N.	,,	67° S.

CONJUNCTIONS—

August	*6th*	at	4- 9	P.M.	with	Mars	(Planet	4°-22′ S.)
,,	*8th*	,,	5-53	A.M.	,,	Saturn	,,	3°-47′ S.
,,	*10th*	,,	9-37	,,	,,	Venus	,,	0°- 2′ S.
,,	*10th*	,,	8-45	P.M.	,,	Mercury	,,	1°-17′ N.
,,	*27th*	,,	4-53	A.M.	,,	Jupiter	,,	5°-27′ S.

The Moon will enter the Penumbra of the Earth, but not the Umbra, on the 25th at 3-30 A.M.

The Planets.

Mercury—Will be in superior conjunction with the Sun on the 14th and will then become an evening star, but too near to the Sun to be visible during the month.

Venus—Is still a morning star, but approaches superior conjunction with the Sun which will occur on the 12th of September, so this planet will hardly be visible during the month.

Mars—Also a morning star, rises from three and a half to four hours before the Sun. Position on the 15th R. A. 5·48 Dec. 23°-33′ N. in Taurus.

Jupiter—Rises at about 9-30 P.M. at the beginning of the month and at about 7-30 at its close. Position on the 15th R. A. 23·52 Dec. 2°-25′ S. in Pisces.

Saturn—A morning star, rises from two to three and a half hours before the Sun. Position on the 15th R. A. 6·51 Dec. 22°-19′ N. in Gemini.

Uranus.—Position on the 15th R. A. 21·4 Dec. 17°-28′ S. in Capricornus.

Neptune.—Position on the 15th R. A. 8·12 Dec. 19°-38′ N. in Cancer.

The Sun.

There will be an annular eclipse of the Sun on the morning of the 11th, commencing at 1-26 A.M. in Longitude 145°-24′ North and Latitude 22°-54′ North, and ending at 7-18 A.M. in Longitude 122°-24′ West and Latitude 22°-0′ South. It will consequently not be visible in India.

For the month of September 1915.

Sidereal time at 8 p.m.

	H.	M.	S.
September 1st	18	38	41
,, *8th*	19	6	17
,, *15th*	19	33	53
,, *22nd*	20	1	29
,, *29th*	20	29	5

From this table the constellations visible in India during the evenings in September can be ascertained by a reference to a Star Chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

The Moon.

PHASES—

September	*1st*	at 8-26	P.M.	Last quarter.
,,	*9th*	,, 4-22	,,	New Moon.
,,	*16th*	,, 12-21	A.M.	First quarter.
,,	*23rd*	,, 3- 5	P.M.	Full Moon. (The Harvest Moon).

OCCULTATIONS—

September	*1st*	at 2-16	A.M.	The Pleiades	Between	83° N.	and	50° N.
,,	*2nd*	,, 11-14	P.M.	Nath	,,	32° S.	,,	62° S.
,,	*15th*	,, 1-42	,,	Antares	,,	8° N.	,,	60° S.
,,	*20th*	,, 2·41	A.M.	Uranus	,,	51° N.	,,	27° S.

CONJUNCTIONS—

September	*4th*	at	12-34	P.M.	with	Mars	(Planet	2°-45′ S.)
,,	*4th*	,,	7-36	,,	,,	Saturn	,,	3°-32′ S.
,,	*9th*	,,	5-53	,,	,,	Venus	,,	4°-17′ N.
,,	*11th*	,,	11-20	A.M.	,,	Mercury	,,	3°-51′ N.
,,	*23rd*	,,	6-53	,,	,,	Jupiter	,,	5°-11′ S.

The Planets.

Mercury—Now an evening star, sets about an hour later than the Sun on the 1st and about an hour and a half later on the 30th, so he will be visible in clear skies throughout the month. He will be in conjunction with Spica in Virgo at 8-30 P.M. on the 21st, the star being only one minute of arc to the south of the planet. He will be at greatest elongation east 26°-2′ on the 28th.

Venus—Is a morning star until the 12th, when she will be in superior conjunction with the Sun, and then becomes an evening star again, but too near to the Sun to be visible during the month.

Mars—Is a morning star rising four hours before the Sun on the 1st and nearly five hours before by the 30th. Position on the 15th R. A. 7·14 Dec. 22°-59′ N. in Gemini. He will be in conjunction with Saturn on the 11th at 4-32 A.M.

Jupiter—Will be in opposition to the Sun on the 17th, rising at sunset on that evening and being on the meridian at midnight. Position on the 15th R. A. 23·39 Dec. 3°-55′ S. in Pisces, below the Great Square.

Saturn—Is a morning star. Position on the 15th R. A. 7·3 Dec. 22°-3′ N. in Gemini.

Uranus.—Position on the 15th R. A. 20·59 Dec. 17°-49′ S. in Capricornus.

Neptune.—Position on the 15th R. A. 8·16 Dec. 19°-25′ N. in Cancer.

The Sun.

The Sun will enter the sign of Libra at 8-54 A.M. on the 24th being the autumnal equinox.

Notices of the Society.

Telegraphic Address.

THE address of the Society has been registered at the Telegraph Office, Calcutta. Telegrams should be addressed " Astronomy," Calcutta.

Addresses of Officers.

Owing to inconvenience which has arisen from addressing the officers of the Society at their private address, it has been decided to receive communications on the business of the Society in future as follows :—

	To
Money Orders or letters containing money or cheques.	RAI BAHADUR U. L. BANERJEE, Office of the Accountant-General, Bengal, Imperial Secretariat (Treasury) Buildings, Calcutta.
All other communications ...	(*Name*) L. DEMETRIUS, ESQ. (*Designation*) Business Secretary of the Astronomical Society of India, Imperial Secretariat (Treasury) Buildings, Calcutta.

It is requested that communications may be addressed accordingly.

Officers and Council.

For the Session 1914-15.

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Report of the Meetings of the Society held on Tuesday, the 11th May, Tuesday, the 1st June, and Tuesday, the 6th July 1915.

The papers, read at the Meetings, are published in this issue.

Some Facts and Hypotheses regarding Variable Stars.

By the Rev. A. C. Ridsdale, M.A., F.R.A.S., F.R. Met. Soc., M. Lond. Math. S., F.Ph.S., A.L.C.M., Foreign Member of Societe Astronomique de France.

The vast majority of the stars are as invariable in their brightness as they are in their apparent positions in the sky. But there are many exceptions and these exceptions are sufficiently numerous to entitle variable stars to be placed in a distinct class by themselves, and within this class of variable stars there are many sub-classes. Thus some show a gradual and alternate increase and decrease of light between definite limits, occurring within regular intervals. Others attain a certain maximum and then decline to absolute extinction, and then again re-appear. Some are continuous in their processes of change. Others are quite irregular in their fluctuations. Others have variable maxima and minima. Others have blazed out and never been seen again. Some have long periods and others have short and so forth. Very little attention curiously enough had been given by astronomers to these various classes of variable stars until about twenty years ago. The credit of the discovery of several hundreds of such stars is due chiefly to the labours of quite a few astronomers such as Dr. Chandler, J. E. Gore, and Dr. Roberts of the Cape Observatory. In view of the fact that this sort of work is highly interesting and is well within the compass of amateurs, it is curious that it should have been so neglected. The binocular and even the naked eye has accomplished most of the spade work in this direction. The variation is judged by comparisons made with neighbouring stars. Of late the number of discoveries made has been greatly increased by the introduction of the photographic dry-plate, a large number have been detected by the comparison of the photographic star charts made at the American observatories of Cambridge and Harvard. The photographed spectra of stars which present a peculiar "colonnaded" appearance immediately mark them off as variables. The photographic method has been especially successful in showing us the extraordinarily large number of variables that are to be found in star clusters and nebulæ. But for ordinary single variable stars there is no better method than that of the naked eye or the mere opera glass, comparing the variable with adjacent stars at the time of its maximum and minimum. It must then be carefully noted to which of the neighbouring stars it is then equal, or a shade brighter or fainter. A really useful work can be done in this direction by the amateur. For it demands no expensive instruments nor any mathematical knowledge and skill, but only a modicum of patience and zeal. The professionals of the observatories gladly welcome records of observations sent in by the amateur, especially as owing to more pressing and technical work, they have little time themselves to devote to the observation of variables. For it must be admitted that some time must necessarily be wasted in extracting these comparatively few variables (which only number about 20 in a million) from the mass of the ordinary denizens of the sky, which are of no peculiar interest. In order to obtain precise quantitative results in the matter of the variation of the light of variables however, instruments of great precision have lately been invented for accurately measuring their varying brightness. Such are the "photometers." They are of two distinct types. The first depends upon the equalization of two lights, and the second on the extinction of light. In the first method, the standard light of a known star, or of an artificial star is varied in a measurable manner, until it is reduced to the same magnitude as that of the variable under discussion. Thus a graduated wedge of neutral-tinted glass can be passed in front of the standard star until the star is dimmed so as to equal in magnitude the variable. If the variable is brighter than the known comparison star, of course the wedge process must be reversed, and be used upon the variable. The better method, however, is that of extinction, as then we have no need of a comparison star. The wedge is passed in front of the variable until its light is just extinguished. The reading at which the extinction occurs varies with the brightness of the star, and hence its brightness can be measured. There is one drawback to this method, namely, its greater liability to error due to the uncertainties of the atmosphere. Hence it is still necessary to check the state of the atmosphere first of all by observing the error in the extinction point of a standard star, and thus to be able to measure accurately at the time of observation the true magnitude of the variable. Variables possess very different ranges of variation. Some only range between a fraction of a magnitude. Others range through as many as eight magnitudes, and are as much as a thousand times brighter at maximum than at minimum. In many cases both their colour and spectra change regularly during the course of their variations. Dr. Chandler's catalogue of 1896 contains 383 stars asserted to be unquestionably variable. Of these 300 are regularly periodic. Of these again he makes fourteen to belong to the Algol type, twenty to the Eta Aquilæ class, and no less than 250 to the Omicron Ceti type. There are 6 with periods varying from 25 to 60 days, it being doubtful as to which class they should be assigned. Thirty are certainly wholly irregular in their variation, and there are about 50 stars whose period has not yet been assigned, and about 150 which are suspected of variation. The new variables are mostly telescopic. When a new variable is discovered, it is now customary to designate it either by the name of the discoverer or by one of the last letters of the alphabet joined with its constellation. Professor Pickering and Bailey of Harvard were the first to make the startling discovery that a vastly preponderating number of variables can be found in certain of the star clusters. Some clusters contain none, others a very large number. In star-cluster Messier 5, in Libra, there are 85 variables out of a total of only 900 stars, in Omega Centauri there are 122, and in Messier 3 in Canes Venatici there are as many as 132. Altogether 600 variables have been found in star clusters up to the present. The variations of these star-cluster variables are curiously alike. They nearly all go through a cycle of an average of 12½ hours, ranging from a 10-hour to a 14-hour period. They all slowly and gradually lose their light, and then remain at about half-brightness for some time, and then suddenly rush back to their maxima with startling rapidity. This suddenness of the return to full light is very remarkable, and hitherto the phenomenon has received no satisfactory explanation. Some variables are very irregular in their fluctuations. The most remarkable of such stars is Eta Argus, or Eta Carinæ, 59 degrees south (it can be well observed from Calcutta, but is too far south to be seen from England or North Europe), which varies from the first magnitude as in 1843, down to the seventh magnitude; which is its present brightness. Between 1677, when Halley observed it, and 1800, as far as can be judged from the existing records, Eta Argus oscillated in brightness between the second and fourth magnitude. Between 1800 and 1826 it rose rapidly in brightness, and between 1838 and 1850 it was never below standard first magnitude. Careful observations were made of its variations by J. Herschel in 1837 at the Cape Observatory. He records how astonished he was on December 16, 1837, at coming across an apparently new star of the first magnitude. He, however, soon recognized it from its position as Eta Argus, and adds that it increased till January 2, 1838, until it equalled Alpha Centauri. It decreased again till it was only equal to Aldebaran, but blazed up in 1843, till it was second only to Sirius in the whole heavens. At its brightest it gives 25,000 times more light than at its dimmest. Eta Argus is enveloped in a nebula. Professor Loomis is of opinion that after a further period of watching this star, it may not improbably be found to have a period of about 70 years, but if this is really so, it is absolutely unique among the variables. Several variables are known such as R. Andromedæ which possess as large or even larger a range of variation than Eta Argus, but none are nearly so bright. R. Andromedæ is never brighter than the sixth magnitude and sinks to the thirteenth. Eta Argus is a most puzzling source of speculation. The vastness of the changes that must take place there absolutely staggers the imagination.

But perhaps the most curious of all celestial phenomena are the so-called temporary stars or "Novæ." Such stars suddenly burst into existence as it were and then as a rule gradually fade away. There are fifteen recorded cases of stars suddenly blazing up and then fading away again. Hipparchus drew up his famous catalogue as a result of seeing a Nova in 134 B.C., his object being to leave behind him a record of the sky as it appeared in his day, in view of possible future change. A Nova was observed in 389 A.D. in Aquila. Another famous Nova was the star seen by Tycho when out walking one November evening in 1572. It appeared in Cassiopæa, and became as bright as Venus and was even visible by day. But after 15 months, it absolutely disappeared, and has never been seen again. Janesen observed a Nova in Cygnus in the year 1600, of the 3rd magnitude. Kepler has recorded that he observed a star in Ophiuchus, which became more brilliant than Jupiter, and after two years faded rapidly away, leaving absolutely no trace behind it. In May 1860 a new star blazed out in Corona Borealis. It was noticed by at least five observers who have recorded their discovery. And Schmidt, who was examining that part of the heavens a week before the discovery, gives it as absolutely certain it was not there before the above date. Ten years later, he discovered a new star of the 3rd magnitude in Cygnus. In a few weeks it faded away. Huggins examined it spectroscopically, and found it similar to our Sun when at its maximum, but as it faded away its spectrum changed to that of a nebula with three bright lines. Altogether eight Novæ have been recorded as observed in the 19th century. Of late years the most notable Nova is that of Auriga, discovered in 1892 by an amateur astronomer named Anderson at Edinburgh. It quickly reached the fourth magnitude, but after three months it sank to the twelfth, after another four it again rose to the ninth, and then faded away. This star was afterwards found on a plate exposed at Harvard on December 10, 1891, but it was not to be found on a plate exposed two days earlier. Its spectrum was examined, and was found to be double, one a bright-line, and the other an absorption spectrum. The lines too were shifted in such a way as to indicate that two stars were moving in opposite directions; the bright-line mass receding from, and the dark-line mass approaching us. Their velocities were exceedingly large and variable ranging up to 500 miles a second. It has been conjectured, that in the case of Eta Argus, two large bodies may have passed very near each other and thus produced great tidal disturbances, causing immense eruptions corresponding to solar prominencies, only on a vastly larger scale. Eight months later the star which had sunk to the 11th magnitude rose again to the ninth, and then Campbell found its spectrum to have become that of a planetary nebula. If astronomers had the leisure to carefully observe all the multitudes of the smaller stars, a vast number would be probably found to be Novæ. There are certainly important physical resemblances between those already observed and examined. But much more work needs to be done on such stars, before we can hope to arrive at any true explanation of their vagaries. Many hypotheses have been put forward. These sudden conflagrations might possibly be caused by two dark bodies colliding, and setting up enormous heat by impact. Or again, a star too faint to have been seen before, might be lighted up by plunging through a nebulous mass of matter. The latter hypothesis seems preferable to the former, since on the former supposition, the sudden sinking down to invisibility could hardly be accounted for. The last Nova was discovered only 13 years ago in Perseus. It came to be surrounded by a nebula which was apparently spreading out at an enormous rate into space. It looked as though the star was ejecting matter that was travelling outward at a velocity equal to that of light, or nearly 200,000 miles a second. It is probable, however, that there was in reality no emission of matter at such enormous velocity outward from the star, but that the star, in passing through a nebula, and in so doing becoming incandescent, was thus lighting it up. We were thus beholding the actual motion of light, as it travelled out and away from the incandescent star, at a rate of 180,000 miles a second. If this is the true theory, we can calculate that the Nova must have been at a distance from us of 300 light years. As a sub-division of the temporary stars, it may be mentioned the "Missing stars." By comparing the present aspect of the heavens and modern catalogues with ancient records and star atlases, many stars are now found to be missing. No doubt many such "missing" stars can be accounted for on the hypothesis of mistaken entries, whether on the part of the recorder, or in the reduction of the observation, or even in the printing. It is certain that in not a few cases one of the planets has been mistaken for a star. There is no known instance of a new star appearing and remaining permanently bright. However, it is certain that there are genuine cases of missing stars, which cannot be explained away by any supposition of mistaken entries. It may be that such stars are in reality periodic, possessing a periodicity far exceeding the limits of time within which the heavens have been observed with any scientific accuracy. In this case they will at some future epoch re-appear. Quite another type of variable star includes the regularly periodic variables. These can be divided roughly into three classes. The first class we will call the short-period variables. The most notable of these are Delta Cepheus, Eta Aquilæ, and B. Lyræ. Delta Cepheus passes from minimum to maximum in 38 hours and from maximum to minimum in 91 hours. Eta Aquilæ departs from and returns to maximum in a 7·189 days cycle. Beta Lyræ, which was discovered to be a variable by Goodricke in 1789, is a most curious and interesting variable. It has two maxima and two minima of unequal values. The whole period being 12·5 days. From minimum which is 4½ magnitude, it rises in 2½ days to its greatest maximum of 3·4, it then gradually sinks in 5 days to 3·9 its lesser minimum, and in 4 days more rises to its lesser maximum of 3·5, and then rapidly sinks again to its greatest minimum of 4·5. A further very remarkable fact is that this period is not constant, but is probably itself periodic. From 1784 onwards the period was lengthening, but the lengthening was not constant but became gradually slower, until in 1840 the lengthening ceased, and since then the period has been shortening. So much for the short period variables. The most conspicuous of our second class or the long-period variables is Omicron Ceti, generally known as Mira—"The Wonderful." This was the first variable to be subjected to scientific scrutiny. David Fabricius notified his discovery on the 13th August of 1596. It has been carefully observed ever since. Its period is 11 months. During most of this time, though invisible to the naked eye, it can be easily seen with the aid of binoculars. Once in 11 months it rises rapidly to its maximum, remains at maximum for about a fortnight, and then gradually faints away to its former long period of faintness, taking about three months out of the eleven to make its changes. Its maximum is not constant however. Sometimes it attains to the brightness of a brighter second magnitude star, and sometimes not even to that of a fourth magnitude. The period of return to maxima is not constant, but varies by several weeks. A large majority of the variables belong to the Mira class of long-period, all of them being of a distinctly reddish hue, and most having a "colonnaded" bright-line spectrum. The mean period of variation which Argelander computes as 331·3 days is not constant, but subject to a larger periodical fluctuation of 29,700 days during which the mean period of 331·3 days varies to the extent of plus or minus 25 days. Its maximum variation in brightness is also probably periodic. At its maximum its spectrum shows a large number of bright lines, most of them probably due to hydrogen, but many as yet remain unidentified. The strange conduct of such stars as Mira may perhaps be due to eruptions similar in kind to, though vastly greater in scale than, the solar prominences. Their periodicity is after all no more mysterious than is the periodicity of the sun-spots. There are less than 100 stars of the third class of periodical-variables known to us, whose most notable member is Algol or Beta Persei, the "Demon star." Its R. A. is 3 hours and Decl. 40 degrees 23 minutes. Two smaller stars will be seen on either side of it. In Autumn after sunset it will be in the N. E., in Spring in the N. W., and in Winter north of the Zenith. The shortness and great regularity of the variations of this Algol type ranging from 4 hours up to 13·2 days is a characteristic. They suffer a partial eclipse at short intervals. When at its brightest Algol is of 2·1 magnitude, and when least bright is less than 3·8. Hence at minimum it is only one-sixth as bright as at maximum. Its whole period is 2·89 days, which is constant, except for a very slow secular lengthening. It falls from maximum to minimum in 1½ hours, remains at minimum for 20 minutes, and returns to maximum in 3½ hours. These changes have been noticed from ancient times, but were not studied accurately until Goodricke pointed them out in 1782. The spectroscope has proved that such variables as Algol are binaries, too close to be separated by any telescope. The shift of the lines of the spectrum shows Algol as alternately approaching and retreating from us, as though it were one star revolving in an orbit. From 12 to 18 hours before obscuration Algol is receding from us at 27 miles a second, after the minimum it is approaching us at the same rate. The brighter component is regularly eclipsed by the darker one, their orbits being in the same plane with the Earth. In other cases where the diminution of light is less marked than in the case of Algol, both stars are probably bright. When one is behind the other, we should receive less light than when they are side by side. In the case of

Algol it can be calculated that Algol is 3,250,000 miles distant from his dark companion, and that their diameters are 840,000 miles and 1,060,000 miles respectively. Their united mass is two-thirds of the Sun's mass, and their density only one-fifth of his. Judging from certain irregularities in the proper motion of this pair, it is probable that the pair is itself revolving around another distant dark body in a period of 130 years. The irregularities, however, may with equal probability be due to a slow revolution of the orbital apsides of the pair. One of the most remarkable of the variables of the Algol type is V. Puppis, lately discovered by Dr. Roberts. Its period is only 1·5 days. The astounding conclusion has been arrived at, that the two components are revolving round one another in actual contact. We will now take a further survey of the hypotheses we have already touched upon, to account for these curious variations of star magnitude. One of the most striking things in the whole range of astronomy is the suddenness and the vast scale of the outburst of light on the part of certain types of variable stars. Many hypotheses more or less satisfactory have been put forward to account for these astounding phenomena. Certainly no single explanation could account for all the various types of variable stars, and probably no sure and safe explanation can as yet be given for irregular variables. We will hazard a few hypotheses. Perhaps in some cases the outbursts may be due to the collision from time to time between two previously dark or semi-dark bodies. We know for several reasons that there do exist dark bodies, and that they may move with great velocity. The outburst would thus appear where previously nothing had been seen. The objection to this theory is the rapidity with which the conflagration dies down, until it soon becomes invisible. Another objection to the collision theory is that, when we consider the smallness of the diameter of stars compared with the vastness of the distances between them in space, calculations of probabilities of collisions would not lead us to expect anything approaching the number of the temporary stars actually observed. On the other hand it is not necessary to suppose an actual collision of their surfaces. It would be sufficient in many cases for them to pass very near each other, in order to produce very vast upheavals and consequent outbursts of light. Perhaps a better theory for temporary stars, is that a dark body may become incandescent by passing with great velocity through a nebulous mass. The gradual dying down of the light would correspond to its gradual exit from the nebula, as the nebulous matter on the outskirts became more and more rarified, and hence the star became less and less incandescent. It is not impossible that these outbursts are due to something akin to solar prominences on a vastly greater scale. In the case of the Nova of 1866, Huggins found its spectrum greatly resembled that of the Sun, and that it behaved in a manner very similar to the Sun's spectrum during periods of great solar activity. The position of the spectrum lines showed that the outburst was due to glowing hydrogen travelling outwards at an enormous velocity. Its spectrum, like our Sun's, was a continuous one, crossed by dark absorption lines. Huggins attributed the outburst merely to an exceptionally vast emission of hydrogen, which by its own light and by heating up the whole surface of the star was sufficient, he thought, to account for the great accession of light. We know the red flames round the Sun are caused by eruptions of hydrogen from his interior, and that these eruptions are accompanied by a great brightening of portions of his surface, which we call faculæ. Newton thought that outbursts were due to the falling into the star of bodies of a cometary nature. But this hypothesis has many objections, and in any case it could not account for periodicity. Herschel considered the variations nothing more than magnified Sun spots, and that the periodicity could be accounted for by the combination of axial rotation with the periodicity of the spots themselves, in like manner as our Sun has a spot-periodicity of approximately 11 years. The light of the variable would be greatest when spots were least and *vice versâ*. If an observer were far enough away, he would perceive our Sun to be a variable star, although indeed the variation would be very much less than that of any star which we denominate as "variable." It is not in the least impossible to the nature of stellar composition, to suppose that very much vaster spot-systems could exist in other stars than in our Sun, without inducing disruption or disintigration. May not another hypothesis be not altogether impossible, namely, that some stars may owing to enormous rotational velocity be spheroids of so great oblateness, as to have the form of their flat disks, something after the fashion of Saturn and his rings, and many of the nabulæ? May not the axis of rotation vary in inclination towards the Earth, so as sometimes to be seen perpendicularly when it would give its maximum light, and sometimes to be seen edgewise and then to be too thin to be visible? This theory would at best account for "periodicity." Again, may it not be that some stars are revolving, along with their surrounding nebula, and that the nebula may extend out from the star very irregularly, or be very irregular in density, in such a manner as to present to our view a much thicker veil to the star on one side, as star and nebula rotate together, than on another. Again may there not be planets in other systems of greater size though of vastly less density than their primaries (Saturn, for example, is far less dense than the Sun), so that in circulating in their orbits, which may periodically vary in inclination, they may thus cut off sometimes more and sometimes less of the light of their primaries, and thereby account for the varying maxima and minima of so many of the variables. Another theory to account for temporary stars, and also variable stars of the Mira class, has been put forward by Lockyer. He supposes that such stars are in a primitive condition of close aggregates of meteoric bodies, not yet condensed or compact globes, and that each such aggregate has another smaller aggregate circulating round it in a very eccentric elliptical orbit with very small perihelion distance, such that when in perihelion, the one meteoric aggregate will graze the other, and thus set up an immense number of violent collisions between individual meteorites, without disturbing the general orbital motion as a whole. The great irregularity of the stars of this class seems, however, to be an objection although not an altogether insuperable one to such a theory. It is very probable that the more regular and punctual variables may all of them be proved to be spectroscopic binaries ; the variation being due in part at least to eclipse, and also in part perhaps to certain tidal interactions, the nature of which is at present obscure. The odd and even minima occurring as they do in several instances at unequal intervals, certainly indicate very eccentric orbits. We will conclude by venturing to suggest, that the true explanation of the variations of the greater number of variables will be found to be, not in any one single hypothesis, such as we have put forward above, but in every variety of combination of these hypotheses.

Note on the Proper Motion of 61 Virginis (B.D.—17°3813).

By T. P. BHASKAR SHASTRI, B.A.

THE star 61 Virginis (Mag. 5th) lies in the portion of the heavens allotted to the Nizamiah Observatory for the astrographic catalogue.

Plate No. 126 was exposed on the 17th March 1913 (=1913·205) the coordinates of the plate centre, reduced to the Epoch 1900·0 being approximately R. A. 13h. 16m. 00s. Decl.—17° 00′ 00″. The position of the star (for 1900·0) as given in Washington A. G. C. is—

R. A. 13h. 13m. 10·73s. Decl.—17° 45′ 13·5″ (Ep. 1894·9) or in "Standard coordinates" referred to the above plate centre.

$\xi' = 4{\cdot}9386$ $\eta' = 22{\cdot}0607$

while the measures given by the plate are

$X' = 4{\cdot}8740$ $y = 22{\cdot}1234$

The differences

$X - \xi = -{\cdot}0646$ $y - \eta' = +{\cdot}0627$

are due to the proper motion of the star in an interval of 18·3 years.

Two subsequent plates Nos. 511, 521 exposed on the 18th February 1915 (=1915·131) and 11th March 1915 (=1915·189) give differences :—

$X - \xi' = -{\cdot}0720$	$y - \eta' = +{\cdot}0710$
$X - \xi' = -{\cdot}0720$	$y - \eta' = +{\cdot}0680$
Mean $= -{\cdot}0720$	Mean $= +{\cdot}0695$

due to the proper motion in an interval of 20·3 years. Burnham in his General Catalogue of Double Stars (No. 6447) gives :—

"The change is due to the proper motion of A which is given from meridian positions :—

Auwers	1·515″ in 225·9°
Porter	1·513″ in 225·7° "

while Burnham himself derives the following Proper Motion from a discussion of a set of four measures

1·481″ in 226·6°

Converting these into R. A. and Decl. we get the following values of the annual P.M.

		ΔX	ΔY	Epoch.
	Auwers :—	—1·054″	—1·088″	
	Porter :—	—1·057″	—1·083″	
	Burnham :—	—1·018″	—1·076″	1883·04
Hyderabad	Plate 126	—1·059″	—1·028″	1913·20
	Plate 521 Plate 511	—1·064″	—1·027″	1915·16

This star has a faint companion of the 10th Magnitude and is one of the pairs first discovered by Herschel.

Note on "What is the Nature of the 'Resisting Medium' in Space."

BY THE REV. A. C. RIDSDALE, M.A., F.R.A.S., F.R. MET. SOC., M. LOND. MATH. S., F.PH.S., A.L.C.M., FOREIGN MEMBER OF SOCIETE ASTRONOMIQUE DE FRANCE.

A PECULIARITY of certain of the comets, notably Encke's, is that their periods are gradually decreasing. Encke first discovered in 1824 that its period is shortened each revolution by about 2½ hours. Since his time its period has diminished by as much as 2 days and 3 hours. He found it was impossible to account for this diminution of the period by admitting errors in the computed masses of the planets which would have disturbed the comet in its orbital path. He, therefore, was led to attribute the cause to the existence of a resisting medium in the neighbourhood of the Sun. For such a resisting medium would diminish the major axis and eccentricity of the comet's orbit, and thereby increase its mean motion, without affecting the inclination of the orbit or the longitude of its nodes. He, therefore, assumed that the interplanetary space contained something of sufficient density to oppose the motion of comets moving in their orbits. This opposition or resistance must be of the nature of a tangential force, tangential to the comet's orbit. By the joint action of its own velocity and the Sun's attraction a comet's path is determined. These two forces are antagonistic. A resisting medium will reduce the velocity of a comet, and then the Sun's will be able to force it to describe a smaller orbit. And if the orbit be diminished, then the periodic time will be diminished in the same ratio. The resisting medium increases in density towards the Sun's centre. The path of the comet would then be not an ellipse but a spiral. It would eventually fall into the Sun. As to what this "resisting medium" may be is by no means agreed upon. Arago considers it to be the interstellar ether itself. But this theory seems to be highly improbable for many reasons. A sounder hypothesis is that this "resisting medium" is an atmosphere surrounding and belonging to the Sun, and that it increases in density in some such proportion as the inverse cube of his distance. If this be so, then it is quite certain from sound mathematical principles, that it must itself be circulating around the Sun with nearly equal rotational velocity. And then the result would *not* be what is observed in the case of Encke's comet. Its orbit would depend on the relation between the original velocity of the comet on the one hand, and that of the layers of the solar atmosphere on the other. At first no doubt acceleration would be produced, until the comet's orbital eccentricity became zero. Then it can be mathematically demonstrated that its major axis would no longer be diminished, that its path would never become spiral, and hence its tendency would *not* be to fall into the Sun. Whatever then may be the true explanation of this "resisting force," which makes a comet describe a diminishing orbit, and hence accelerate its velocity—and this force I am convinced most certainly exists—it must be conceived of in any case as a compound of two forces, the radial force acting from the Sun, and a tangential force opposite to its motion. If this latter force then be not due to the solar atmosphere, it may possibly be due to a comet's "jets," which it belches forth towards the Sun in the neighbourhood of perihelion, exercising upon its centre of gravity a repulsive action, which would be sufficient to change and diminish its orbital path when in the Sun's neighbourhood. And certain researches of Argelander on the comet of 1811 undoubtedly support this latter theory.

The Bengali and Semitic Seasons.

By W. J. Simmons, Esq., B.A., F.R.A.S.

The seasons legitimately come within our jurisdiction; they are astronomical phenomena in the sense that they depend on the Sun's apparent annual motion in declination, due to the Earth's axis being tilted in relation to the plane of the Earth's orbit. I must assume that you are all familiar with the diagram given in such books as Heath's 20th Century "Atlas of Astronomy," and in passing will merely remind you that our word season comes to us through the French language, from the Latin verb Sero, I plant, or sow; Sérére, to plant or sow. The seasons are everywhere associated with changes on the Earth's surface, with conditions of temperature, moisture, and necessarily of vegetation. The word (season) itself is obviously related to the sowing period of the year, or spring time, as if that were emphatically the season of seasons. These periods occur in different parts of the Earth at different times of the year; and their demarcations are conventionally adjusted. In Great Britain, Spring begins in February, Summer with May, Autumn with August-September, and Winter with November-December. In America and Canada Spring begins on the 1st March, Summer on the 1st June, Autumn on the 1st September, and Winter on the 1st December. It would almost seem as if the year ought to be divided into four seasons, which should begin when the Sun reaches the four cardinal points that mark his career along the ecliptic. Spring from this point of view should begin on the 21st-22nd March, the Vernal Equinox; Summer on the 21st-22nd June, the Summer Solstice; Autumn on the 21st-22nd September, the Autumnal Equinox; and Winter on the 21st-22nd December, the Winter Solstice. But, at the outset, I must observe that this four-point rule does not apply to the whole Earth. At the Poles there are only two seasons, a long and dreary Winter and a short-lived Summer. In tropical regions there are practically three seasons, the hot season, the rainy season and the cold weather. It is here that for the purposes of this Note the conventional adjustment of these annual periods comes in. In Bengal, as amongst the ancient Hebrews, there are six seasons. First, Summer or *Grishmo*, which includes the Bengali months of Bysack and Joistho (middle of April to the middle of June); second, the Rains or *Barsa*, which includes the Bengali months of Ashar and Sraban (middle of June to middle of August); third, Autumn or *Sharat*, corresponding to the Bengali months Bhadra and Aswin (middle of August to middle of October); fourth, *Heemunto* or the period of heavy dews, including Kartic and Aughrayan (middle of October to middle of December); fifth, Winter or *Sheet*, including Pous and Magh (middle of December to middle of February); and sixth, the Spring, or *Basunto*, including Falgun and Choitra, the small-pox season (middle of February to middle of April). This division into six seasons occurs we are told by Romesh Chunder Dutt in his History of Civilization in Ancient India (Book II, Chapter VII); in the Vedas themselves, a work which carries us back to B.C. 1400 to 1000 B.C. The six seasons of the year were then called respectively *Madhu*, *Madhava*, *Sukra*, *Sachi*, *Nabha*, *Nabhasya*. I have referred (unsuccessfully, I regret to say) to Wilson's Translation of the Rig Veda, and have not been able to trace the passage on which Romesh Chunder Dutt relies for this archaic six-fold division of the year. With the ancient Hebrews, the year was also divided into six seasons. Those familiar with the most widely known portion of ancient Hebrew literature preserved to us in the Old Testament, will remember it is therein recorded that after Noah came forth from the Ark, Yahveh said, not to Noah, but in His own heart, "while the Earth remaineth seed time and harvest, and cold and heat, and summer and winter, and day and night, shall not cease." It is curious that day and night should be included as a kind of Appendix to the category of the seasons; but if regard be had to the changes in temperature, &c., which day and night bring with them, one can perhaps understand how these diurnal phenomena might, amongst early peoples, come to be regarded as seasons. The Arabs, another Semitic people, to this day retain the same six-fold division of the early Hebrews.

The first of the Hebrew seasons was "Harvest" (for they do not seem to have begun with the Spring time). It ran from the middle of April to the middle of June, and corresponded to the Summer season or *Grishmo* of the Indians in this Province. The air was warm, and even hot, and in the plains of Palestine severe at this period. The second season, or "the heat," ran from the middle of June to the middle of August. The heat was then intense. The Arabs call this season "the Vernal Summer," and you will recognize that it corresponds with our rainy season or *Barsa* in Bengal. The third Hebrew season or "Season of Fruits" corresponded to the Autumn or *Sharat* of Bengal. During these first three seasons there are no showers, rain being as scarce in Summer as snow. Hence the Hebrew proverb as "Snow in Summer, and as rain in harvest, so honour is not seemly for a fool" (Prov. XXXI-1). This was the Hebrew season of heavy dews, which in their literature are an emblem of Divine grace and goodness. The fourth of the Hebrew seasons was "seed-time"; it included the period from early October to early December, and corresponded to the Bengali *Heemunto*. The former, or early rain, referred to in the Jewish Scriptures fell during this period. The fifth season was "Winter" and like the Bengali *Sheet* ran from the middle of December until the middle of February. The sixth, and last season was "the cold," and corresponded to the Bengali "*Basunto*." It began in the middle of February and ended in the middle of April. The rains were then taking off, and the latest falls which occurred in early April were called the "latter rain." Those familiar with the Hebrew Scriptures will remember the former and the latter rain are referred to in passages occurring in some of the books attributed to the Prophets of Israel (Jer. V-24; Jo. II-23). Our Indian friends, who are necessarily familiar with the Sanskrit literature, only accessible to us, as is the case with the Hebrew literature, in translations should, if I may venture to say so, be able to follow up the line of investigation, which I have only briefly suggested.

In my enumeration of the Hebrew seasons, which as I have already observed still obtains in Arabia, you will not fail to be struck with the fact that the six-fold division of the year, into periods of two months each corresponds notably with the six-fold division of the Bengali year. But you also cannot fail to be impressed by the marked differences which obtain between the seasons as they prevail in a Mediterranean country, and as we know them in Bengal. The Hebrew harvest was contemporaneous with our spring time in Bengal; and again they had hail and severe thunderstorms, the torrent brooks of hallowed Israel, were in spate and the streams filled their channels in the Palestinian winter, which fell during our Bengali *Sheet,* that enjoyable period when we have the unclouded skies and the bracing weather that make Calcutta so great an attraction to our cold weather visitors. The Hebrews as was also the case according to Romesh Chunder Dutt with the early Aryans in the Vedic period associated their seasons with gods and religious festivals. I venture to suggest that all of us, whether Christian, Hindu or Jew, do the same to this hour. The Christian Easter and Christmas are merely survivals, with altered meanings attached to them of archaic seasonal festivals. But here we approach barbed wire entanglements, which lie outside the scope of our Society and of this Note; the object of which will have been attained if I have succeeded in drawing your attention to an interesting subject which I commend to you for further study.

Note on "The Possibility of a Collision between the Earth and another heavenly body."

By the Rev. A. C. Ridsdale, M.A., F.R.A.S., F.R.Met. Soc., M. Lond. Math. S., F.Ph.S., A.L.C.M., Foreign Member of Societe Astronomique de France.

A learned paper by the Mathematician Lalande, entitled "Réflexions sur les comêtes qui peuvent S'approcher de la Terre," which was read before the Acadamie des Sciences early in the year 1773, caused a serious panic throughout France. The mistake arose from a garbled account of his paper, which appeared in the "Gazette de France." An explanation from the pen of Lalande himself did little to restore calm, and the Archbishop of Paris was solicted to appoint a forty hours' prayer and fast to prepare for the Judgment Day. The real purpose of Lalande's paper was to find by calculation the distances of the nodes of sixty-one comets from the Earth's orbit, and also the distances of these comets from the plane of the ecliptic, at the moment when the comet's radii victores were equal to unity. By means of these elements, he showed which of the comets could most nearly approach the Earth. Two comets have approached the Earth's orbit to within a distance of half a million and 850 thousand miles respectively, namely, the comets of 1680 and 1684. But in both cases the Earth was at the time far from the points where the comets cut the ecliptic plane. But the comet of 1770 passed through the ecliptic at a point only 168 thousand miles distant from where the Earth passed but five hours later. The comet of 1680 is of peculiar interest, in that according to the calculations of Halley and Newton it was the comet which produced so world-wide a sensation in 1106 and 531 of our era, announced the death of Cæsar in B.C. 43, appeared at the taking of Troy, and still earlier, in the time of the Minoan King Ogyges in B.C. 1769, who according to ancient Greek traditions Herodotus tells us was contemporary with a second Deluge. But the most interesting point in connection with this comet is that it probably appeared in 2344 B.C., the date fixed by chronologists for the Mosaic Deluge. Whiston would have it that this comet was the *cause* of the Flood. According to him, it caused a prodigious tide, not only in the waters of the sea, but also in those beneath the solid crust, in the region of Armenia, which was nearest the comet at the moment of its close passage to the Earth. A considerable scare was created by Olber's prediction that Biela's comet would intersect the Earth's orbit at 10 o'clock on the night of October 29, 1832. The distance of the comet's node from the Earth's orbit was 4·66 radii of the Earth or 18,600 miles, and since the radius of this comet's atmosphere was over five such radii, it was evident that the Earth's orbit would intersect some portion of the comet's atmosphere. The scare-mongers had, however, overlooked Olber's statement that at the moment when the comet would be crossing its node, the Earth could not then be less than forty-nine millions of miles distant from it! Lambert in 1765 wrote:—"The near approach of comets might occasion the most dire catastrophies to our Earth—cover it again with the waters of a deluge, cause it to be consumed by fire, crush it to atoms, or at least divert it from its orbit, carry away its moon, or, worse still, carry away itself, and bearing it off to remote regions, compel it to endure a winter, which neither man nor animals would be capable of resisting." And Lalande has calculated that "if a comet of the same mass as the Earth approached to within a distance of one quarter of that of the Moon, it would suffice to raise the waters of the oceans 2,000 fathoms, submerging the Continents." But we hasten to point out, that this calculation ignores the important fact that it would take many hours of proximity for a comet (independently of its mass) to be able to raise such tides. Whereas, if a comet be, say, 40,000 miles distant at perigee, it would have passed [if moving (as is a reasonable supposition) at parabolic velocity], 50,000 miles distant only one hour later, and would then be over 23 degrees vertically distant from the position it occupied over the Earth when at perigee. Or to take an extreme case, in one-half hour only, a comet could have changed its vertical position in respect to our globe by over 80 degrees. Comets pass indeed, with such rapidity in the vicinity of the Earth, that the effects of their mere attraction need occasion no alarm. It is only by actually striking against the Earth, that they could be the cause of serious or fatal injury to our globe. On the supposition that the mass of the heavenly body were comparable to that of the Earth, very serious results for our globe might ensue. The axis of the Earth and its rotational motion might be altered. In this case the seas would quit their ancient positions, in order to precipitate themselves towards the new equator. A great proportion at least of the human race would be destroyed in the deluge, or by the shock of the terrible collision. All monuments of civilization would be in a moment annihilated. Indeed, it is not impossible that such an event has actually taken place in a not very remote past. This would explain why the oceans have receded from the high mountains, upon which they have left incontestable marks of their sojourn. It would explain the comparative newness of the moral world of rational beings, whose monuments date back but for a few thousand years. The human race, reduced by such a catastrophe to a small number of individuals, and solely occupied for a length of time with the care of its own preservation, must have lost entirely the remembrance of the sciences and arts. And when the progress of time made these wants felt anew, it was necessary to begin again, as if man had been newly placed upon the Earth. To obtain, however, a truly correct view of the effects of a collision with a heavenly body of a supposed mass about equal to that of the Earth, we must not ignore the great principle of the "law of the conservation of energy," by which the kinetic energy of a body can be transformed into heat. Thus, knowing the weight and velocity of the Earth, we can calculate the exact amount of heat that would be generated, were the Earth to be suddenly stopped in its course. This heat would be sufficient not only to fuse the entire globe, but to reduce it in great part to vapour. This collision between the Earth and another body of equal mass and velocity would result in the annihilation of all movement of translation, and the Earth and body together, fused into one single-heated mass, would fall into the Sun within two months after the catastrophe.

Memoranda for Observers.

Standard Time of India is adopted in these Memoranda.

For the month of October 1915.

Sidereal Time at 8 p.m.

	H.	M.	S.
October 1st	20	36	58
,, *8th*	21	4	34
,, *15th*	21	32	10
,, *22nd*	21	59	45
,, *29th*	22	27	21

From this table the constellations visible in India during the evenings in October can be ascertained by a reference to a Star Chart, as the above hours of sidereal time represent the hours of right ascension on the meridian.

The Moon.

PHASES—

October	*1st*	at	3-14 P.M.	Last Quarter.
,,	*9th*	,,	3-12 A.M.	New Moon.
,,	*15th*	,,	7-21 P.M.	First Quarter.
,,	*23rd*	,,	5-45 A.M.	Full Moon.
,,	*31st*	,,	10-9 A.M.	Last Quarter.

OCCULTATIONS—

October	*3rd*	at	7-10 A.M.	Mars	Between	90° N.	and	11° N.
,,	*12th*	,,	7-56 P.M.	Antares	,,	17° N.	,,	48° S.
,,	*17th*	,,	7-37 A.M.	Uranus	,,	59° N.	,,	20° S.
,,	*25th*	,,	5-46 P.M.	The Pleiades	,,	90° N.	,,	22° N.

CONJUNCTIONS—

October	*2nd*	at	7-53 A.M.	with Saturn	(Planet	3° 12′ S.)
,,	*3rd*	,,	7-11 A.M.	,, Mars	,,	0° 43′ S.
,,	*9th*	,,	8-0 P.M.	,, Venus	,,	6° 11′ N.
,,	*10th*	,,	5-6 P.M.	,, Mercury	,,	1° 40′ N.
,,	*20th*	,,	7-55 A.M.	,, Jupiter	,,	4° 57′ S.
,,	*29th*	,,	5-10 P.M.	,, Saturn	,,	2° 53′ S.

The Planets.

Mercury—is an evening star until the 22nd, when he will be in inferior conjunction with the Sun at 7-30 P.M., and then becomes a morning star. He will be visible during the first week of the month, setting a little more than an hour after the Sun.

Venus—now an evening star, sets within an hour after sunset throughout the month.

Mars—a morning star, rises between four and five hours before the Sun all through the month. Position on the 15th R. A. 8·27 Dec. 20° 23′ N. in Cancer to the west of Præsepe. On the morning of the 12th, he will be in conjunction with Neptune.

Jupiter—is now high in the heavens before midnight. Position on the 15th R. A. 23·26 Dec. 5° 20′ S. still below the Great Square.

Saturn—a morning star, will be at quadrature with the Sun on the 10th, being then on the meridian at sunrise. Position on the 15th R. A. 7·10 Dec. 21° 53′ N. in Gemini.

Uranus.—Position on the 15th R. A. 20·57 Dec. 17° 55′ S. in Capricornus.

Neptune.—Position on the 15th R. A. 8·19 Dec. 19° 18′ N. in Cancer.

For the month of November 1915.

Sidereal Time at 8 p.m.

	H.	M.	S.
November 1st	22	39	11
,, *8th*	23	6	47
,, *15th*	23	34	23
,, *22nd*	0	1	59
,, *29th*	0	29	35

From this table the constellations visible in India during the evenings in November can be ascertained by a reference to a Star Chart, as the above hours of sidereal time represent the hours of right ascension on the meridian.

The Moon.

PHASES—

November	*7th*	at	1-22 P.M.	New Moon.
,,	*14th*	,,	4-33 A.M.	First Quarter.
,,	*21st*	,,	11-6 P.M.	Full Moon.
,,	*30th*	,,	3-40 A.M.	Last Quarter.

OCCULTATIONS—

November	*13th*	at	1-49 P.M.	Uranus	Between	72° N.	and	3° S.
,,	*27th*	,,	8-32 A.M.	Neptune	,,	90° N.	,,	33° N.

CONJUNCTIONS—

November	*6th*	at	9-46 A.M.	with	Mercury	(Planet	7° 32′	North.)
,,	*8th*	,,	4-6 P.M.	,,	Venus	,,	4° 46′	,,
,,	*16th*	,,	11-25 A.M.	,,	Jupiter	,,	4° 59′	South.
,,	*25th*	,,	10-38 P.M.	,,	Saturn	,,	2° 41′	,,
,,	*29th*	,,	5-47 A.M.	,,	Mars	,,	3° 52′	North.

The Planets.

Mercury—is a morning star rising in Virgo about an hour before the Sun at the beginning of the month, and in Libra less than an hour before on the 30th. He will be at greatest elongation 18° 57′ W. on the morning of the 7th.

Venus—an evening star, gradually increases her distance above the Sun and by the end of the month will set nearly an hour and a half after the Sun.

Mars—a morning star, will be in quadrature with the Sun on the 10th, being then on the meridian at about sunrise. Position on the 15th R. A. 8·27 Dec. 16° 59′ N. in Leo, a little to the north-west of Regulus.

Jupiter—who has been retrograding since July 19th, will be stationary on the 15th and will afterwards resume his eastward course. Position on the 15th R. A. 23·20 Dec. 5° 49′ S. in Pisces.

Saturn—a morning star, now rises before midnight. Position on the 15th R. A. 7·10 Dec. 21° 55′ N. in Gemini.

Uranus.—Position on the 15th R. A. 20·58 Dec. 17° 51′ S. in Capricornus.

Neptune.—Position on the 15th R. A. 8·19 Dec. 19° 16′ N. in Cancer.

Notices of the Society.

Telegraphic Address.

THE address of the Society has been registered at the Telegraph Office, Calcutta. Telegrams should be addressed "Astronomy," Calcutta.

Addresses of Officers.

Owing to inconvenience which has arisen from addressing the officers of the Society at their private address, it has been decided to receive communications on the business of the Society in future as follows :—

	To
Money Orders or letters containing money or cheques.	RAI BAHADUR U. L. BANERJEE, Office of the Accountant-General, Bengal, Imperial Secretariat (Treasury) Buildings, Calcutta.
All other communications ...	(*Name*) L. DEMETRIUS, ESQ. (*Designation*) Business Secretary of the Astronomical Society of India, Imperial Secretariat (Treasury) Buildings, Calcutta.

It is requested that communications may be addressed accordingly.

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POPULAR LECTURES.

The Life History of a World

BY THE HON'BLE MR. W. A. LEE, F.R.M.S.

THE history of the Earth has always been a favourite subject of speculation and inquiry. Ever since mankind began to take an intelligent interest in the causes of phenomena there has been the desire to investigate the past history of our planet, and in ancient times these speculations generally took the form of more or less fantastic imaginings built upon assumptions and theories, and with little or no basis of actual fact.

Later, when observations multiplied exceedingly and were compared together, the conclusions arrived at became more and more sure, until to-day we are able to present such an array of facts as justify us in holding clearly defined opinions regarding much of the past life of the Earth.

Applying to the other planets the knowledge we have gained of our own world, we are assisted in the interpretation of many phenomena, and when we carry the analogy of the solar system into the other parts of the visible universe we are enabled to understand much that would otherwise have no meaning.

At the outset of our investigation we are oppressed by our limitations. The world remains very much the same sort of world during the lifetime of a man, there has indeed been little or no change in the Earth since the commencement of recorded history, and a man might well imagine the world to be permanent and immutable.

Consider for a moment how the world would look to a mosquito, or, better still, to one of the day flies, those curious creatures which only live for a few hours, and eat no food, having no mouth. Such a fly would see flowers, trees, grass, but would see neither change nor growth, and if it could judge only by what it could see it would be justified in believing that the leaves of the tree and the petals of the flower had existed always and would last for ever. It would seem to such a fly that to speak of the growth of a tree or of a flower would be almost a verbal absurdity. The lifetime of a day fly is all too short to judge of growths that require weeks or months or years to become manifest.

Just in the same way the life of a man is too short to observe changes in the Earth's condition, even the lifetime of the human race only covers the later stages of the life of the world, and carries us back but a little way in its life history.

In fact, we are dependent not so much on what we can see as on the inferences and deductions and calculations we are able to make, in order to arrive at any clear knowledge of the past history of the world and of the solar system, or of a stellar system.

When we inquire into the history of the world the first change we discover was in comparatively recent times, about 100,000 years ago. At that time the climate of northern Europe, including the British Isles, was positively Arctic. Most of Europe was buried under a thick coat of ice, which persisted all the year round. When geologists found evidence of great masses of ice in Great Britain and other parts of Europe they called the period in which this arctic climate existed the glacial epoch, and the cause of the glacial epoch gave rise to much speculation until it was discovered that there is an astronomical explanation.

The Earth revolves round the Sun, as you know, in an orbit, that is nearly a circle. It is not quite a circle, but is an ellipse, a circle a bit drawn out in one direction. If the Earth's orbit were a circle the Sun would be in the middle of it, but being an ellipse the Sun is not in the middle but in a focus of the ellipse. So that as the Earth's orbit is an ellipse, and the Sun is in one focus of the ellipse, the Earth, as it revolves round the Sun in its orbit, is a little nearer the Sun as it passes round the focus of the ellipse and is a little further from the Sun as it passes round the further portion of the orbit. At present the Earth is nearest the Sun when it is winter and furthest when it is summer, in the northern hemisphere. That means that the Earth is passing round the furthest and longest part of its orbit in the summer, giving a long mild summer, and that the shorter and nearer part of the orbit is traversed in winter, giving a short and warm winter.

In the southern hemisphere the conditions are reversed, and the winter is long and cold and the summer is short and warm. It is not so much the warmth of the months when the Earth is nearest the Sun that has the greatest effect on the climate, but the season which is longest, and in the southern hemisphere the summer, being short, although it is warm, is not long enough to counteract the cooling of the long cold winter, and consequently the antarctic regions are cooler than the arctic, and the antarctic ice is of greater extent than the arctic.

Now just imagine what would be the result of an exaggeration of these differences of climate. Suppose that the Earth's orbit, instead of being almost a circle, was really a much more pronounced ellipse, a good deal more drawn out in one direction, say four times as much. This would have the effect of making the long antarctic winter very much longer, and the summer much shorter, while in the arctic regions the summer would be much longer and the winter would be shorter. It is clear that under these circumstances the antarctic ice would increase very greatly, and would probably extend into South America and Africa, while the arctic ice would melt away.

We have already imagined that the Earth's orbit is, so to speak, more elliptical; now please imagine that the direction of the Earth's axis swings slowly round the pole of the orbit. that the Earth reels as it rotates, so that the Earth may be furthest from the Sun when it is winter in the northern hemisphere. Then we should have a long cold winter in the northern hemisphere with a short warm summer, and instead of a great increase of antarctic ice the antarctic ice would melt and dwindle away and the arctic ice would increase and extend. The cold in these long winters would be so intense that the ice would not be melted in summer, and almost the whole of Europe and the whole of northern Asia would be gradually covered with a thick sheet of ice. We should, indeed, have a glacial epoch, so that if the conditions I have asked you to imagine could ever have come to pass there must have resulted a glacial epoch.

Now the eccentricity of the Earth's orbit is not always the same, it varies, and 200,000 years ago it actually was four times as much as it is now, so that 200,000 years ago there must have been a glacial epoch. Moreover, owing to the way in which the attraction of the Sun and the Moon acts upon the equatorial bulge of the Earth, the Earth's axis is continually changing in direction, and its direction changes in such a way as to bring each of the seasons in turn to that part of the orbit which is nearest to the Sun, the whole circuit taking over 20,000 years. The effect of this is that whereas now the southern hemisphere has a long cold winter, 10,000 years ago the conditions were reversed and the northern hemisphere had the long winter. So, you see, when there was a glacial epoch the glacial condition oscillated from the southern to the northern hemisphere and back again to the southern hemisphere, and so on, each oscillation taking about 10,000 years. During a glacial epoch the arctic ice would gradually, for 10,000 years, extend southward over Europe till it reached a maximum, and then gradually recede, for another 10,000 years, while the antarctic ice is extending, and then again the arctic ice extends. In one glacial epoch there may be more than one such oscillation, giving an alternation of an arctic climate with a mild or warm climate, each lasting roughly 10,000 years, including the period of transition. The last glacial epoch extended more or less continuously for about 150,000 years, and terminated less than 100,000 years ago.

The visible rocks upon the Earth's surface are, broadly, of two kinds, those that are sedimentary, formed by the consolidation of deposits thrown down in shallow seas and other shallow waters, and those that were formed with the help of the action of fire. The deposits which have become the sedimentary rocks must of course have been formed exceedingly slowly, and as their total thickness is many thousands of feet the time during which these rocks were being formed can only be estimated in millions of years, and saw many changes in the Earth.

The sedimentary rocks often bear evidence of movement since their formation; sometimes the strata, instead of being horizontal, are tilted up to a more or less steep slant, sometimes they are sheared off by one part having slipped down or having been upheaved, and sometimes the strata are split or crumpled into folds. This folding or crumpling or splitting of the Earth's crust is responsible for most of the great mountain ranges, such as the Andes, the Rocky Mountains, the Alps, and the Himalaya. It is probable that the Pacific Ocean was formed at the same time as the Andes, and the land to the west of South America disappeared then.

The lines of the great earthfolds, along which mountain ranges have been formed, perhaps I should say are still being formed, may be easily discerned. You see the line of folds running more or less continuously from the Pyrenees to the Himalaya and down through Burma and Sumatra, and another running round the Pacific, on the eastern side of the Pacific giving rise to the mountain chains and on the western side passing through Japan, and a succession of islands to New Zealand.

Geologists divide up the whole time in which the sedimentary rocks have been deposited into periods, which are distinguished from each other by the character of the rocks deposited in each and the fossils they contain. Geologists are not agreed as to the precise length of time that any of these periods occupied, the only thing that appears certain is that they were very long, many of them, perhaps all of them, millions of years. For convenience these geological periods are grouped into three eras, called, beginning with the oldest, the Palæozoic, the Mesozoic, and the Kainozoic.

In the most recent of these three eras, the Kainozoic, there have been many changes in the arrangement of land and water. It has seen the linking of Europe and Asia, the separation of America from the arctic land, and of Great Britain from the continent of Europe, the raising of the Andes, and the disappearance into the Pacific of the high land which was to the west of South America. In the middle of the Kainozoic era there was an outbreak of volcanic activity accompanied by Earth movements which involved much change in the land and sea areas, before this there was a quiet interval, and at the beginning of the era we find another outburst of volcanic energy.

The previous era, the Mesozoic, was marked by quiet, during which the Earth movements were slow and comparatively slight.

Then we come to the Palæozoic era, and here we find the changes were so considerable that we must look at them a little more in detail. Near the end of the Palæozoic era was the carboniferous period, in which the coal measures of the world were formed, and towards the end of the carboniferous period there was an outbreak of volcanic activity, and violent Earth movements that did untold damage to the world's store of coal, especially in India. Coal having been formed over enormous areas, the Earth movements split, tore, crushed and sheared in all directions the strata containing coal. In some places portions of the strata were lifted, and adjacent portions sunk, so that the displacement of the strata is as much as many hundreds of feet, and the shearing of the strata is visible now as what geologists call a fault, where the strata have moved and there is a vertical split, so that across the split the strata are not continuous. Not content with raising large parts of the coal strata high into the air where the weather has gradually denuded and washed away all traces of coal, laying bare the underlying rocks, there was at the same time much volcanic activity which forced molten rock into the strata of coal, burning up and destroying a very large quantity.

We have endeavoured to reconstruct the outlines of the land in each period by a study of the arrangement of the plants and animals as shown by their fossil remains, but it is like reading a book of which many pages are missing, but more and more of Nature's manuscript is being discovered and deciphered every day, and the new facts are being sorted into their places like missing parts of a zig-zag puzzle.

In the carboniferous period the northern flora indicate a continent which connected Europe and America, and another which connected India, Australia, South Africa and Brazil.

The period before the carboniferous, the Devonian, was a period of great volcanic activity. There were active volcanoes in many parts of the world which are not recognised as actively volcanic now, such as the British Isles.

Before the Devonian there was a quiet period, the Silurian, in which the Earth movements were slow. A map of North America in Silurian times has been prepared by Mr. Bailey Willis. It shows North America as a series of islands, not recognisable as his native land by an American citizen of to-day.

The period before the Silurian, the Ordovician, was a period marked by extremely active volcanoes and great Earth movements, and a map of the world in the Ordovician period would show a curious reversal of land and water ; indeed, it is remarkable that whenever we find a continent to have been submerged we find some evidence suggesting that on the opposite point of the Earth's surface a sea has become dry land.

Now we come to the earliest period in which the sedimentary rocks contain fossil remains of plants and animals, the Cambrian period. This was a period of comparative volcanic calm though there were plenty of volcanoes in this period.

An attempt to reconstruct the arrangement of land and water in Cambrian times by making a map of that period, would show that the southern countries of South America, Chili, the Argentine, Uruguay, etc., were under water. The British Isles were apparently joined to Norway and perhaps also to Greenland and Canada, while India, most of Europe and Eastern Asia, most of Africa, and Australia were connected together, and there was a Pacific continent, whose limits we of course do not know.

In maps of the world of all these periods India is shown as dry land. India is indeed one of the oldest countries in the world. As far as we know, peninsular India, that is the southern portion of India, is one of the few parts of the Earth's surface that has never been submerged under the ocean during the ages covered by the geological record; compared with it the whole of northern and middle India, including the Palæozoic coal measures may be called young, and even the great mountains on our northern frontier are of but yesterday. Are they not, indeed, still growing?

Beyond the Palæozoic era we come to the very interesting Eozoic era during which life first appeared on the Earth and only the most primitive forms of life existed. This era may have been very long, even as long or longer than any of the three which I have roughly sketched, but the geological record is meagre. But we know that in the latter part of this era there was little volcanic action, though at an earlier stage volcanoes were numerous and violent.

There is proof that in several of the geological periods there was ice in many parts of the world where now there is none, proving that those parts had a colder climate in some past ages than they have now. Even as far back as the Cambrian period, the earliest in the Palæozoic era, there are evidences of ice in, for example, Australia. This might lead one to suppose that the world is warmer now than in the Cambrian period. I described to you at some length the causes which operate to produce an ice age, and there can be no doubt that whenever in the Cambrian period the Earth's eccentricity was sufficiently large, there must have been a glacial epoch, and ice in Australia then is exactly what one would expect. But the ice age in the southern hemisphere, or indeed anywhere in the world, would not continue throughout the Cambrian period.

No conclusion regarding the average climate of the world in the Cambrian period can therefore be based upon finding traces of ice having been present at that time, the recurring glacial epochs fully account for all such manifestations and the world may have been on the whole appreciably hotter than now, in spite of ice having scratched the rocks in Australia.

Having got so far it will be interesting to review the facts recorded. We have seen that throughout the geological ages during which the stratified rocks were formed volcanic activity and quiescence alternated, and Earth movements of various degrees of slowness interchanged the areas of land and sea in most parts of the globe, and tilted, folded and crumpled the strata in very many places, and we look for some explanation. To find this we must look a long way below the surface of the Earth, and here again we are at a serious disadvantage. Our deepest mine is only a depth of something like one mile from the surface, only one four-thousandth part of the way to the centre. I am afraid these figures do not convey a very clear idea. A four-thousandth part of course means a very little, but how little ? Let me illustrate. Imagine a globe eight feet in diameter, the size of an ordinary projected picture on the screen, on the same scale the thickness of a finger nail would represent a mile.

But although the depth to which we have penetrated is as nothing in comparison with the size of the Earth, yet we have learned some very valuable and suggestive lessons. In the first place, the temperature increases as we go down. The rate of increase is difficult to measure, and is said not to be exactly the same in every place, but if we say that the temperature increases everywhere at the rate of between 80 and 90 degrees for a mile of depth we shall state the facts with all needful accuracy.

We do not know whether the temperature goes on increasing indefinitely at the same rate. For instance, is the temperature at a depth of 20 miles 1,600°, at 50 miles 4,000°, and so on ? The temperature probably does not increase continuously towards the centre of the Earth, but at what depth does the increase of temperature cease and what is the temperature of the central part of the Earth ?

These are questions we cannot answer, but we have no doubt it is very hot. Perhaps only as hot as a steel-making furnace, perhaps as hot as the electric arc, perhaps even hotter.

Whatever be the temperature of the interior of the Earth it is clear that as it is hotter than the surface the internal heat must be continually conducted through to the cooler surface, and radiated away into space. The Earth is therefore cooling down. As the Earth is cooling it must be contracting, all substances, even rocks, contract as they cool. If the Earth is contracting it must be sensibly smaller than it was many millions of years ago, and this would fully account for crumplings and foldings of the Earth's rocky crust, as it endeavoured to adjust itself to the reducing circumference. This would also account for those Earth movements which have alternately raised land and again submerged it below the surface of the ocean. As the Earth contracted the crust would be subjected to strains of compression, and as soon as these strains increased beyond what the materials could stand, a part would slip or crumple, or a large area would be depressed. It must be remembered that such depressions or crumplings of the Earth's surface only refer to a thin film, as it were on the surface. Coming back for a moment to our imaginary globe, 10 feet in diameter, the average height of a continent would not amount to as much as a coat of paint. The height of the highest mountain does not amount to as much as $\frac{1}{8}$ of an inch, while another $\frac{1}{8}$ of an inch would represent the depth of the deepest ocean. Consequently all the Earth movements we are able to see are contained in a crust measuring an average of less than $\frac{1}{16}$ of an inch in thickness on our 10 feet globe. There is no difficulty, therefore, in assuming all the upheavals and depressions in the Earth's surface to be due to deformation of the crust caused by contraction as the Earth gradually cools.

Some light is thrown upon the interior of the Earth by several lines of investigation. In the first place we know that the weight of the Earth is between 5 and 6 times as much as the weight of a globe of the same size would be. We know also that the weight of the rocks on the surface is about $2\frac{1}{2}$ times the weight of water. So that the Earth is more than twice as heavy as it consisted only of rocks like those on the surface.

The radio-activity of the surface of the Earth is such as to suggest that the layer of radio-active minerals is 45 miles thick, and that the whole globe of the Earth, except the outer layer 45 miles thick, is composed of some other materials not radio-active. Iron is a mineral of which there is a great deal in the solar system, it is not radio-active, and a large central core consisting largely of iron would seem to meet all these requirements.

Much may be learned also regarding the Earth by a study of earthquakes. An earthquake sends out vibrations all around. One set of these vibrations passes along the surface of the ground. These are undulations just like waves of the sea or ripples on a pond. But at a considerable distance from the centre of the earthquake the vertical movement is lost and the only movement is horizontal. Suppose that an earthquake occurs at this point, the vibration waves pass round the surface in this direction and they also travel through the substance of the Earth in all directions, so an observer stationed at this point marked C would be able to record two sets of vibrations, one set arriving to him through the substance of the Earth and the other set arriving around the surface: the direct line through the Earth being so much shorter these vibrations arrive earlier. Moreover these vibrations travel more quickly than those on the surface; this proves that the Earth is more and more solid the deeper we go, because vibrations are transmitted more rapidly in more rigid material. Professor Milne, the seismologist, thinks that the Earth has a rocky crust about 40 miles thick and that below that depth there is harder material. If an earthquake occurs at a given point the vibration would travel to a point on the Earth 30 degrees away at a speed of 5 miles per second, 70 degrees away at 5¼ miles per second and right across to the opposite side 5½ miles per second, showing that the rigidity of the materials of the globe increases towards the centre. It is interesting to enquire how far the known materials that we find on the Earth's surface will account for the speed at which earthquake vibrations pass through the Earth. The most complete investigations of the rigidity of rocks are those which have been made in Japan, and these show that the elasticity and rigidity of some kinds of Eozoic rocks would account for a wave speed of 1¾ miles per second, some of the Palæozoic rocks 2¾ to 3½ miles per second, and some of the oldest Archæn rocks over 4 miles per second, so that it is clear that the oldest of the igneous rocks are more solid, so to speak, more rigid than the geologically newer rocks, but that even these igneous rocks, which form the foundation of the Earth's crust, are not sufficiently solid to account for the speeds at which vibrations are conveyed through the interior of the Earth. There is another series of vibrations set up by earthquakes. The vibrations which we have just been considering are waves of compression, but there are also waves of distortion, which tend to twist the substance through which they are propagated. Waves of distortion travel at a slower speed than waves of compression and they are differently affected, they move more slowly through a more solid substance, and it is found that waves of distortion while they travel at approximately the same speed through the substance of the Earth in all directions as long as they do not reach the centre, they are retarded if they pass right through the middle. The paths of the vibrations are curved which is perhaps the manner in which vibrations travel through the Earth going deeper than the straight path because of the different rigidity at greater depths. I have referred several times to the crust of the Earth, but I do not wish it to be supposed that below the crust there is anything like a fluid interior. The interior of the Earth may be very hot, may in fact be as hot as molten metal and it may act in many respects as though the material were fluid, and it may flow, but such effects are due merely to the enormous weight of the strata above. The weight is so great that at a sufficient depth any metal would flow like a liquid. The Earth is in fact as rigid as a ball of iron, but iron itself is plastic even under the comparatively high pressure to which we can subject it, which are as nothing to the pressures for in the interior of the Earth. Even under the 40-mile crust of the rocks we find on the surface the pressure is more than 100 tons on every square inch, a pressure under which a somewhat brittle rock like marble becomes quite plastic, and this depth is only represented by the width of one's finger on a 10 feet globe. Earthquakes originate at comparatively small depths below the surface, probably none more than about 20 miles depth, at which the Assam Earthquake of 1897 has been supposed to have been originated.

This earthquake, by the way, was the greatest earthquake that has been recorded in history, that is to say, it was felt as a great earthquake over a larger area than any other has been, which indicates that it had an unusually deep origin. The Charleston Earthquake of 1886 originated at a depth of about 12 miles. The earthquakes which have been seriously felt over a considerable area have been what has been called earthquakes of dislocation, readjustments of the crust of the Earth which has become strained in some way, generally by shrinkage, until it is no longer able to resist the strain and a more or less sudden adjustment is made involving enormous masses of rock whose sudden movement sets up vibration in the Earth which are transmitted through the whole globe. Frequently distances that have actually been measured have been found shorter after an earthquake, showing that the Earth has actually contracted, so that the strata have been crumpled to the extent that the distance between two points on the surface has become less.

As the Earth is cooling and contracting there must have been a past age when it was very much hotter, and if the cooling has been continuous we have only to imagine a period sufficiently far back to arrive at a stage when the Earth was a molten globe, still further back it must have been very largely vapour, and still further back we can imagine the Earth expanded to a globe of vapour reaching out to the Moon, which at once leads us to enquire where the Moon was then. It was Professor George Darwin who first investigated mathematically the history of the connection between the Earth and the Moon. From consideration of the tides raised upon the Earth by the action of the Moon he was able to show, and indeed it appeared to be quite clear when once he had pointed it out, that the action of the tides upon the Earth is such as to cause by their friction a gradual retardation of the Earth's rotation, so that the Earth is rotating more and more slowly than it used to. While the tides are retarding the Earth's rotation, they are also retarding the Moon's revolution round the Earth. This seems a very curious proposition, but the method of its action is this: The Moon's attraction raises the tide upon the Earth, and the rotation of the Earth carries that tide, the raised tidal wave, away from the point which is just opposite the Moon, so that the tide upon the Earth is always behind the point where the Moon is straight overhead and the tidal wave raised upon the Earth also of course attracts the Moon, and as the position of the tidal wave on the Earth is always well behind, its attraction on the Moon is not in the same line as the attraction of the solid body of the Earth, but is tending to pull the Moon back and retard its motion of revolution. By its retardation of the Moon's motion in its orbit, it is compelling the Moon to recede further from the Earth, so that the orbit of the Moon is increasing in size owing to the action of the tides on the Earth.

We, therefore, see that in past ages the Moon was nearer the Earth than it is now, and when the Moon was nearer the tides it raised on the Earth were of course greater and had greater effect both in retarding the Earth's rotation and in retarding the Moon's motion in its orbit. Pursuing this line of argument, there must have been a previous time when the Moon was touching the Earth, was indeed part of the Earth. Precisely how it came to separate, it is more than difficult to say, but that it did in some way separate off from the Earth when the Earth was very young, appears as far as we know now to be fairly certain. We have now carried back the history of the Earth to a time when it was molten, perhaps largely vapour, and to a time when the Moon and the Earth were one body, before the Moon's mass separated off from its parent mass, and it will be interesting to see whether we can find in any other parts of the solar system or in the depths of space indications of similar processes having gone on elsewhere.

The planet which is nearest in size to the Earth is Mars. Mars is much smaller than the Earth, not very much more than half the diameter, and it travels round the Sun in an orbit which is half as large as that of the Earth. As Mars is on the side farther from the Sun when it is nearest to the Earth it is well illuminated and well placed for observation in this position. The most distinctive feature in photographs of Mars is the little spot on the visible pole which looks like polar ice. There are some very clearly visible markings which appear on many photographs as a blurry equatorial belt. Observers have at first often expected to see Mars more like the charts which have been published, and which are the result not of one observation but of several, and show some of the well-known "canals," as they have been called, in Mars, lines generally fairly straight, joining dark points, many of which would otherwise be isolated. Expectations of this kind are not realised, but the permanent markings on Mars are generally so hidden by white masses which are thought to be clouds that one may look for them again and again without seeing them. On account of the uncertainty of whether in looking at any point on Mars you may be looking at a cloud or at the real surface or perhaps at an area where there is a slight fog sufficient to obscure all but the most strongly marked and salient features, doubt has been expressed as to whether the canals have any real existence, as to whether they may not be optical illusions induced by long staring at the various points on the surface, and some very curious and interesting experiments have been made by gazing at unconnected points, to see whether the eye could trace lines apparently connecting such points. A series of experiments of this kind were described by Mr. Lane some years ago in which he used a drawing approximately like the principal dark shadings on Mars, but omitting all the fine lines. It was drawn 3½ inches diameter and placed at 20 feet from the person to whom it was shown, in a not very good light. It was shown to several people successively at this distance under this illumination, and they were asked to draw it on paper, and what they produced were very remarkable. They drew imaginary lines connecting the points on the shaded portions. They were not told to draw particular lines, but they were asked to particularly notice the differences in shade, and in the shapes of the points. One of them produced a drawing in which were a complicated series of lines, some parallel. The 5th person to whom the drawing was submitted drew no lines at all. Two of the four were school boys who knew nothing of Mars or its markings. These experiments may perhaps throw some light on the minutest details which are said to have been seen, or on the other hand these markings perhaps really are there on the surface of Mars. It is at any rate clear that if the dark areas on Mars represent water the shapes of the continents and seas on Mars are greatly different to those upon the Earth, the greater part being land and not water. Mars has atmosphere even as we have, and its atmosphere frequently contains cloudy masses which obscure our view of the surface of the planet just as cloudy masses in the Earth's atmosphere would obscure the view of the Earth's surface from another planet, and there are polar caps of something white which looks like ice, and which vary from summer to winter just as polar ice would be expected to do. If Mars has lived through a hot stage as the Earth has, it is now in an older condition than the Earth. It is becoming in fact somewhat elderly. If we assume that Mars really did pass through similar hot stages that we find the Earth has apparently passed through, and compare Mars and the Earth at the same corresponding age, that is in the same condition, we should find that the Earth would retain its heat much longer than Mars. The mass of the Earth, that is what we may call the weight of the Earth if we had suitable scales to weigh both Mars and the Earth, the mass of the Earth is 9 times as great as that of Mars, and therefore under similar conditions of heating the Earth would have 9 times as much heat to part with, but surfaces which are cooling only part with their heat in proportion to their area, and the two globes would lose heat in proportion to their surfaces, so although the Earth would have 9 times as much heat it would only part with 3½ times as much heat in any given period, so that the heat in the Earth would last longer than the heat in Mars in the proportion of 9 to 3½. Mars would, therefore cool and grow older nearly 3 times as fast as the Earth, and if they were formed at the same time Mars would, eventually, cool so as to be in a different condition to the Earth, and to present features which would indicate a greater age.

After Mars let us examine the largest of the planets, the great planet Jupiter. In size Jupiter is a contrast to Mars. There are two well-defined features which are easily seen, one is the darker equatorial bulge and the other is the polar compression caused by the rapidity with which Jupiter rotates. Although he is so large, more than 10 times the diameter of the Earth, his period of rotation is only 10 hours, consequently the equatorial bulge and polar compression are very marked. The lighter markings on Jupiter are no doubt clouds, and the darker markings are rifts through which we see down towards the surface of the planet. Jupiter's atmosphere is very deep, so deep and so continually full of cloud that it is more than doubtful whether we have ever seen the real surface of the planet. We see these cloudy shapes changing more or less slowly or rapidly, but the surface of Jupiter far below is out of our sight, and we do not know what the real diameter of the solid globe may be: we cannot even guess. If the constitution of Jupiter's atmosphere is anything like that of the Earth and under similar conditions, it is not difficult to judge of the depth of the atmosphere. For the purpose of comparison with Jupiter we will take the depth of the Earth's atmosphere in which clouds are formed, similar in appearance to those of Jupiter, to be 7 miles. The upper surface of such a cloud layer in the Earth's atmosphere would be at about a quarter the atmospheric pressure at the Earth's surface. Now if Jupiter's atmosphere is like the Earth's atmosphere the upper surface of his cloud layer is at the same atmospheric pressure. Jupiter is so large and his total weight is so enormous that the force of gravity is 2½ times as great upon Jupiter as upon the Earth, and it is easy to calculate what the pressure must be on Jupiter at any given depth below the upper surface of the cloud layer. If the cloud layer is 13 miles in depth, the pressure on the surface of Jupiter would be over 5½ tons per square inch and the atmosphere would be so compressed that it would be as heavy as water and would be liquified. We know that the atmosphere of Jupiter is not only 13 miles in depth, but at least a hundred miles and perhaps several times as much. Stars have been seen through the edge of the cloud layer as Jupiter has passed in front of them, and although it is difficult to say through what depth of atmosphere such stars have been seen it is at least certain that the depth was many miles. Of course this is a rare phenomenon, because generally the cloud masses are so dense that nothing can be seen through them, but the observation has been made sufficiently often to place it beyond doubt. We are, therefore, faced by this dilemma that the atmosphere is of very great depth, but if it has an atmosphere like that of the Earth the pressures are such as would render most of it liquid.

The whole of the great globe of Jupiter is very much lighter, size for size, than the Earth, indeed it is only about 1½ times the weight of a similar volume of water. If the materials of which Jupiter is composed are at all similar to any of those which are found upon the surface of the Earth, Jupiter would be nearly twice as heavy as he actually is, so that we are obliged to assume either that the materials which form Jupiter's globe are altogether different to the substances of which the smaller planets are composed, or that they exist in Jupiter under very different conditions. In the present state of our knowledge it would be a venturesome, one might also say a wild, assumption, to assume that Jupiter is composed of substances greatly different to those found elsewhere in the solar system, and consequently we are more or less compelled to fall back upon the only remaining possibility, namely, that the globe of Jupiter is in some different condition which makes it and its atmosphere both lighter than the conditions obtaining on the Earth would oblige us to expect. We have only to suppose that Jupiter is in a highly heated condition in order to be able to explain the differences which are apparent between that planet and the Earth, and heat is quite enough to account for the smallness of Jupiter's density, and we are therefore unable to avoid the conclusion that Jupiter is extremely hot.

A very prominent feature on Jupiter is the marking which has been called the Great Red Spot, and which has persisted for many years. It is generally explained as an area from which in some way clouds were removed, and we could see down through the cloud layer to, or near to, the surface of the planet. Exactly what kind of disturbance can have had the effect of clearing Jupiter's atmosphere of cloud over such a large area, and of keeping it clear to such an extent, we have no means even of guessing, but it must have been of the most stupendous character. If we suppose Jupiter and the Earth to have both been at the same extremely hot temperature in some past age, we should find that Jupiter would remain hot far longer than the Earth, because his mass is 315 times that of the Earth and he would therefore obtain 315 times as much heat, while his surface area is only 114 times as great as that of the Earth's surface. So that the heat of Jupiter would last about 3 times as long, and the Earth would cool down 3 times as quickly as Jupiter, so that after the lapse of a certain length of time the Earth would present the appearance of being older than Jupiter, and it is clear from what we have found of the hot condition in which Jupiter exists to-day, that Jupiter, whatever his real age may be, is in a more youthful state than the Earth.

Saturn is the second largest planet in the solar system, it travels round the Sun in an orbit nearly 10 times the diameter of the Earth's orbit and takes nearly 30 years to make a revolution. Its diameter is about 9 times the Earth's diameter. The conclusions to which we were obliged to come respecting the constitution of Jupiter, apply also similarly to Saturn, and Saturn is therefore an extremely hot planet. The rings of Saturn present a phenomenon quite different to anything appearing in connection with all the other planets. It is not necessary for us to go into details as to their constitution, but we may note that Saturn rings could not exist if they were solid, they are subjected to such disturbing forces that they would be broken up even if they consisted of a tenacious metal such as iron or steel. It is, therefore, believed that they consist of a flight of small bodies, solid or liquid, or both, travelling together as a cloud in the shape of a thin ring revolving round the planet. The outer planets, Uranus and Neptune, are somewhat similar to each other in size and smallness of density, each planet being rather more than four times the diameter of the Earth. Their lightness indicates that they also must be hot.

We have seen how the smaller a planet is the more rapidly it must cool, and this is a matter that depends upon the proportion between the surface of a sphere and its volume, and therefore when we examine the smallest astronomical body available to us we should expect to see evidences of old age.

We will consider now the heavenly body which is best placed for observation, being nearest to us, the Moon. Illumination at Full Moon is so direct, with such absence of shadow, that details are not easily seen. A picture of the Moon a little before it is full shows the difference which the angle of illumination makes at the edge, where the hollows and raised portions are so much more clearly defined. You see the darkness of one area, which is called a sea, not because it is really water, but for want of any better and more descriptive term. With oblique illumination it is seen that even this dark space is covered with craters and craterlets and walled plains. Craters of extinct volcanoes are among the most conspicuous objects on the Moon's surface. The diameter of one is over 50 miles and the depth inside the crater is some 17,000 feet. Another is nearly 60 miles in diameter and is some 12,000 feet deep inside. If they are viewed under a small angle of illumination, we can well understand their real shape, and the shadow under one edge of the crater indicates the depth. If you see the crater just at sunrise as it were, the Sun's ray strikes on the very middle of the crater and perhaps lights up a central hill, in one case really a mountain a couple of thousand feet high. The fact that there is no twilight on the Moon, but that there is an absolutely sharp distinction between the full blaze of sunlight and the complete darkness of night, shows that there is no atmosphere, which is also separately proved by observation of stars across which the Moon travels in the sky. The Moon is therefore cold and dead, with the exception of such heat as is received from the Sun during its long day of a fortnight, which heat it parts with in its long night of two weeks' duration.

Let us turn to the Sun, the ruler of the solar system. Here we meet with all the features we found when examining Jupiter but very greatly exaggerated. The Sun is as much larger than Jupiter as Jupiter is larger than the Earth. The Sun is also heavier, bulk for bulk than Jupiter, so that the force of gravity is very much greater on the Sun than on Jupiter. A weight of 4 lbs. on the Earth if taken to Jupiter and weighed there with a spring balance would weigh 10 lbs., and if taken to the Sun and weighed there it would weigh a hundred weight. With this greater force of gravity on the Sun the difficulty of accounting for an atmosphere of considerable depth is enormously increased, but the Sun is manifestly hot, and the explanation occurs to us at once that the great heat renders possible an atmosphere of great depth. The heat of the Sun is so great that it is difficult to suggest any figures that help one to realise its real temperature.

The Sun is, therefore, in an extremely youthful state, so hot that every known substance is vaporised, so hot that in spite of the force of gravity being so great its atmosphere is thousands of miles deep, so hot that rain and hail on the Sun are not water and ice, but iron and other things which only melt at a high temperature.

A sunspot is a space in the outer atmosphere through which we can look down into the depths below. It looks quite dark by comparison with the blazing, glowing clouds around it.

Whatever the age of the Sun may be, measured in centuries, it is still in the enjoyment of the energy of youth, and will not have cooled down to the condition of even the hot giant planets until untold ages have passed.

Let us briefly review what we have noted respecting the solar system. Every body in that system is cooling, and we find that they are in various stages of cooling much as from their different sizes we should expect them. There was therefore probably a time when the Sun was hotter and larger, and a previous time when the Sun was so large as to fill the orbit of the Earth; before that perhaps even the orbit of Neptune. But, then, the Sun would be a nebulous cloud of glowing gas.

The movements of the planets afford some interesting reflections; all the planets revolve round the Sun in planes not greatly inclined to each other and all in the same direction. Moreover the direction of revolution of the planets is the same as the direction of rotation of the Sun. Now what is the probability that these movements are accidentally in the same direction and what are the chances that there is some physical connection between these movements? If a man tells us that he tossed a rupee five times and it came "Heads" every time, we should think it very extraordinary. If he should say that it came heads 10 times successively, we should not readily believe it, for the chances are a thousand to one against, and if he said it happened twenty times consecutively we should feel sure it was not true, for the chances against this are a million to one.

When 7 planets were known the probability that uniformity of direction of movement indicated some relation was very great, and as each successive planet was discovered the probability became greater, until now that hundreds of planets are known, the probability is too great for expression, and it becomes a certainty that the identity of direction of revolution of the planets and the rotation of the Sun are in some way connected.

We are thus driven to the belief that the Sun has contracted from a nebula occupying a vast extent of space and that the formation of the planets and the rotation of the Sun were in some way related.

It has been supposed that the Sun has captured bodies wandering through space and that these have formed the planets, and that the planets have similarly captured their satellites, but there are mathematical difficulties.

It is not understood, for example, how Jupiter could capture a satellite. Jupiter could capture a small body, which might become a minor planet revolving round the Sun; he did capture a comet, which now revolves in a closed orbit, but we do not know of a body which could capture a satellite for Jupiter.

From the solar system we turn to the depths of space, to see whether we find anything which helps us in our investigation anything analogous to what we have seen and have found in our own system.

In the first place, we find the depths of space strewn with stars; as far as the telescope can reach we find stars innumerable.

Many of the names given to astronomical objects, especially by the ancients, show a highly developed imagination, but the appearance of some objects really did suggest their names, for example the Crab Nebula, which seemed like a crab before we photographed it and could see so much of its structure. There is also the America Nebula which obviously suggests North America, and the Trifid Nebula in Sagittarius. It has been suggested that the rifts visible are not really rifts but are caused by the obscuring of the light by some dark body between us and the nebula. Then there is the nebula known as the Owl Nebula from its appearance of having two eyes in the centre. Here again photography has somewhat altered the appearance as it is seen in ordinary telescopes. We might also mention the Dumbbell Nebula which in ordinary telescopes looks much more like a dumbbell than as photographed.

Having found that the solar system may in some bygone time have consisted of a diffused nebula, having probably some motion of rotation, we search the sky to see whether we can find any evidence of the existence of a nebula with these characteristics. In the central portion of the great nebula of Andromeda, there is some suggestion of movement around the centre, but it is not very clearly defined. Here again there are curious rifts or dark places in the nebula, the shape of which in this nebula certainly suggests the presence of dark matter between us and the nebula, perhaps the nearest outlying portions of this nebula are not glowing, or perhaps some other body between us and the nebula cuts off its light. In one photograph of a nebula which is clearly spiral in shape we have once more a rift or dark patch which again may be caused by some dark matter driven across between us and glowing nebula ; in another spiral nebula, there is some suggestion of a Catherine Wheel. All these nebulæ bear evidence of movement which may have originated within the nebula itself or may have resulted from two nebulæ meeting each other ; not meeting quite directly but at a little distance or so as to graze, then they would capture each other and begin to circle round their joint centre and would show a spiral appearance. If there are many spiral nebulæ in the heavens some of these must be seen by us edgewise, and we should accordingly expect to find a number in the sky presenting not their flat rotating side but their edge, and a nebula in the constellation of the Whale has a distinct suggestion of a spiral nebula seen rather obliquely or edgewise, and another nebula which looks like the edge of a lens, and which we are obliged to believe is a spiral, which must of course of necessity be flat, and in another case the outer portions of the spiral are dark and cut off the light of the glowing central portion.

Thousands of nebulæ have been photographed ; of these it is believed that half are spiral, and in gazing upon these spirals it may be that we are looking at the earliest stages in the construction of systems similar to our solar system, and this is in progress all over the visible universe as far as the astronomical camera can see.

If you will allow me I will conclude by quoting " A Dream of Infinity " by DeQuincey, after Richter.

God called up, from dreams, a man into the vestibule of Heaven, saying, " Come thou hither, and see the glories of my kingdom." And to the angels that stood around his throne, God said, "Take him; strip from him his robes of flesh; cleanse his vision, and put a new breath into his nostrils : only, touch not with any change his human heart, the heart that weeps and trembles." It was done; and with a mighty angel for his guide, the man stood ready for his infinite voyage ; and from the terraces of heaven, without sound of farewell, they passed into infinite space.

Sometimes, with the solemn sweep of angel wings, they passed through Saharas of darkness, through wildernesses of death, that divided the worlds of life. Sometimes they passed over threshholds quickening under prophetic motions. Then, from beyond depths counted only in heaven, light dawned as from a sleepy film. By unutterable pace they passed to the light, the light by unutterable pace to them. In a moment, the rush of planets was around them, in a moment, the blaze of suns was upon them.

Then came eternities of twilight, that revealed but were not revealed. On the right hand and on the left hand towered gigantic constellations, that by self repetitions, by answers from afar, by counterpositions, built up triumphal gateways, whose archways and architraves, horizontal, upright, rested, rose, at altitude, by spans, that seemed ghostly from infinitude. Without number were the archways, beyond memory the gateways, past counting the architraves. Within were stairs that scaled the extremities around. Above was below, below was above, to the man stripped of gravitating body. Depth was swallowed up by height insurmountable, height was swallowed up by depth unfathomable.

On a sudden—as thus they rode from infinite to infinite ; on a sudden—as thus they tilted over abysmal worlds ; a mighty cry arose that systems more mysterious, worlds more billowy, other heights, other depths, were coming, were nearing, were at hand !

Then the man sighed and paused, shuddered and wept ; his overladen heart uttered itself in tears ; and he said : " Angel, I will go no farther ; for the spirit of man acheth with this infinitude. Insufferable is the glory. Let me lie down and hide me in the grave from the persecution of the infinite ; for end I see there is none." And from all the listening stars that shone around there issued a choral voice, " Angel, thou knowest that the man speaks truly ; end is there none that ever yet we heard of." " Is there no end ? " The angel solemnly demanded : " Is there indeed no end ? And is this the sorrow that kills you ? "

But no voice answered, that he might answer himself.

Then the angel threw up his glorious hands to the heaven of heavens, saying :—

" End is there none to the Universe ; Lo ! also there is no beginning."

Comets

BY THE REV. J. MITCHELL, M.A., F.R.A.S.

Mysterious visitant whose beauteous light
Among the wandering stars so strangely gleams
Like a proud banner in the train of night
The emblazoned flag of duty it streams
Infinity is written in thy beams
And thought in vain would through the pathless sky
Explore thy secret course, thy circle seems
Too vast for time to grasp. Oh ! can that eye
Which numbers hosts like thee, this atom earth descry.

THIS is the poet's attempt to express his thoughts in reference to Comets ; whether he is correct in his surmising or not, we shall see during the course of this lecture.

We are accustomed to think of the celestial orbs as being the most regular and law-abiding of all created objects. The stars, so far as ordinary sight is concerned, are fixed in space. Centuries pass but they remain precisely in the same place relatively to one another. The Sun is the centre of the solar system and knows no change in brightness or attractive power. The planets with their satellites revolve round the Sun with a perfectly regular and uniform velocity. Order and law reign supreme in the Universe. It is true that occasionally extraordinary phenomena like eclipses occur, but every eclipse, whether solar or lunar, is known beforehand, and each is predicted with the greatest accuracy. But comets, or the vast majority of comets, appear to be exceptions. Some few there are that follow the course of the planets and accept the Sun as their over-lord, but the rest, and this signifies an enormous host, follow their own law. They come when least expected ; from whence they come and whither they go is one great mystery.

Comets until quite recent years have, in every part of the world and in all ages, been regarded as evil portents, presages of disaster. Even as late as the 17th century a certain poet wrote of comets thus :—

" A Blazing Star
Threatens the world with famine, plague and war
To princes death ; to kingdoms many crosses
To all estates, inevitable losses,
To herdsmen rot, to ploughmen hapless seasons
To sailors storms, to cities civil treasons."

In this country comets have, in general, always been regarded as dire portents. An eclipse of the Sun or Moon renders the time being inauspicious and impure, but the rise of a ধূমকেতু (comet) is a still worse portent, *e.g.*, after such an appearance a soldier shall not for 7 days take part in a military expedition. According to the colour and form of a comet its influence for weal or woe depends. Generally speaking, a white tailless or short and straight comet does not produce such evil effects, but a comet in the form of a rainbow is an omen to be dreaded, but if it possesses three crests then the results are direful in the extreme.

101 comets are accounted for thus :—

(1) 25 are produced by fire ; they are blood-red or have the colour of lac. They are found in the East and South and they give rise to a general conflagration.

(2) 25 come from যম. the god of death. They are black in appearance, have crooked tails and are found in the South. They bring death to countless numbers.

(3) The Sun accounts for 25. These are golden in colour and appear in the East and West. Such comets produce unrest and disorder among the princes.

(4) 22 are produced by Mars. They produce hunger and fear and are found in the North and East.

(5) The Moon accounts for 3. These are white and glistening or silvery and their influence on the whole is for good.

(6) Lastly, the Creator himself produces 1. This comet may appear in any part of the sky and the result is universal destruction.

Most of us can remember at least one occasion when the coming of a comet has given rise to the scare that the world would come to an end on a given day. Such a scare got abroad in England in 1872, and in this connection Richard Proctor, the famous Lecturer on Astronomy, tells a good story which has the merit of being true : "In a certain house in Sheffield, Monday, August 12, had been appointed a great washing-day. On the morning of the day, the housekeeper asked for an interview with her master on the subject of the comet. She begged to know if it were really true that the world would be destroyed on that day. Receiving assurances to the contrary, she expressed some degree of satisfaction, "but, Sir," she said, "though what you say may be very true, might it not be just as well after all *to put off the washing-day till to-morrow ?*"

Now it is not to be wondered at, that these mysterious visitants gave, and still give, rise to fears. As we have just stated, regularity and order characterise the celestial orbs generally, but comets appear to know no order. They suddenly appear faint and tiny at first, then in a short time they brighten up, shoot out a long tail until in some cases they span the heavens like a flaming torch ; visible, sometimes, even in the day time, and then as mysteriously diminish and disappear.

Comets vary in apparent size and brightness enormously, and as regards number, who can count them ? Kepler stated that they inhabited the ether as fishes the ocean, and that the ocean was not fuller of fishes than the ether of comets. Probably thousands visit our neighbourhood without being seen. Many are so feeble in brightness that only a powerful telescope or the photographic plate can reveal them. On the other hand, the comet of 1744 equalled Venus in brightness and became visible at noon, and as recently as January 1910 a " day-light " comet appeared in the heavens. Then who can forget the magnificent comet of 1882, as it spanned the East Heavens ? This was my first comet and it impressed me greatly.

Comets to the early inhabitants of the world appeared to have little or no connection with the solar system and scarcely any even with the Universe. What were they ? They differed from each other in appearance, and shape, and some apparently in colour. They appeared in every conceivable portion of the heavens. Sometimes in the East before sunrise, sometimes in the West after sunset. Now they appeared in the northern heavens moving across the familiar stars of the Great Bear, now in the South, cultivating the acquaintance of Orion or the Scorpion. Their true paths in the heavens the ancients were absolutely ignorant of; but later they became aware that in some way or other their increase in size and brilliance was due to the Sun, and they noticed, too, that the tails of comets were always turned away from the Sun. Gradually astronomers began to suggest paths in which comets might move. Tycho Brake thought they might move in circles. Kepler and Galileo believed they traversed the solar system in straight lines. Hevelius generally agreed with Kepler, but he threw out the idea that the path might possibly take the form of a parabola, but it was Sir Isaac Newton who put an end to these hypotheses by connecting the movements of comets with the laws that govern the motions of all the heavenly bodies which move within the sphere of the Sun's attraction. Newton was a godsend to the world of intellect and especially of mathematics and astronomy

And this leads us to the part that Halley played in the discovery of cometary motion. Apart from Halley's connection with the famous comet that bears his name, the world owes more to him than most people realise, for it was largely due to his enthusiasm and generosity that Newton's immortal "Principia" was due, for it was he who urged its writing, it was he who urged the Royal Society to publish it when written, and it was he who bore the entire expense of its publication.

In the Principia, Newton promulgated the theory of gravitation and applied it in many directions, but so far as we are concerned to-night, to the orbit of the great comet of 1680. He stated that it was very probable that some comets might move in elongated ellipses, and that the comet of 1680 might be moving in such an ellipse, and he invited astronomers to apply the principles laid down in his work to all the comets on record. Halley took up the task. He undertook the investigation of the movements of a large number of the comets previously recorded and calculated the paths of 24, to see if any, and if so, which followed the same path. He carefully investigated, in particular, the orbits of the comets of 1531, 1607 and 1682, and he found a remarkable similarity in their elements and he came to the conclusion that they were one and the same comet, and so confident was he that he predicted its return in 1758, and he concluded his memoir as follows: "Wherefore if, according to what we have already said, it should return again about the year 1758 candid posterity will not refuse to acknowledge that this was first discovered by an Englishman."

And candid posterity has given Halley his due, but while giving him his full due as being the first to predict the reappearance of the same comet, great credit must be and is given to the two Frenchmen, Clairant and Lalande, and also the French lady, Mddle. Horteuse Lepande, who completed Halley's work by predicting with greater accuracy the date of the comet's perihelion passage. On its way here the comet had to pass near the planets Saturn and Jupiter, and the perturbations due to these would be very considerable. These the mathematicians took into consideration and the labour involved was immense. Eventually Clairant announced the 13th April 1759 as the date for the perihelion passage. The actual date was the 12th March 1759, a difference of only 32 days, but what are these in 76 years. It was a triumph, for the difficulties of the problem were most formidable. This will be realised to some extent when it is stated that the comet was delayed 618 days by the two planets, 100 being due to Saturn and 518 to Jupiter.

The next appearance of the comet was still more eagerly looked for and even greater preparations were made by the mathematicians. Again Frenchmen were to the fore. This time the perturbations caused by the new planet "Uranus," before this discovered by Sir William Herschel, had to be taken into consideration. The Frenchmen were joined by two German astronomers, one of them, Rosenberger, being one of the most distinguished mathematicians of the age. Not only did he take into consideration the effect of the larger planets but the smaller ones also—Mercury, Venus and Mars. He fixed November 26, 1835, as the date of the perihelion, but the comet actually passed this point on November 16, 1835, 10 days before the calculated date. This was another triumph for gravitational astronomy.

The honour of the prediction of the last return in 1910 belongs to two Englishmen, Drs. Cowell and Crommelin, both Cambridge men. By a much more simplified process of mathematical reasoning they fixed the perihelion passage within 2·7 days of the actual event, and they conclude their memoir with the following significant words: "There is some small disturbing cause at work whose character is not yet recognised." It may be so. Suppose there is another planet beyond Neptune, that small disturbing cause will, one day, we hope, be discovered and then the course of one comet at any rate will be known.

We are thus led to the conclusion that the orbit of a comet such as Halley's, which re-appears after a given period, in this case about 75 years, must be a closed curve, either a circle or an ellipse. The circle does not seem a popular path. All the planets along with their satellites move in ellipses, though these in almost every case are not far removed from circles. But the comet eschews a circle. The few that return to us periodically move in ellipses. Some, like Halley's, are vastly extended approaching parabolas which is what the ellipse becomes, when it becomes infinitely extended, and this is the path of the vast majority of comets that appear. They come from infinite depths of space, fall into the sphere of the Sun's influence, are attracted, circle round the Sun and rebound into space, never to return. Some we say are caught by the Sun's attraction, but how many are not? How many exist beyond and are never seen?

We have just stated that Halley's Comet moves in an ellipse, but what a zig-zag path it must be after all when it can be delayed 618 days by two planets. It must have a most tortuous course as it makes its way past planets and satellites.

Again, we may compare a comet with the planets. The planets in their various paths round the Sun move in planes inclined only at a slight angle to the ecliptic, *i.e.*, the plane of the Earth's orbit. Mercury's orbit is inclined 7°, Venus 3°, and the rest less. The satellites are more variable. The plane of a comet's orbit may be at any angle to the ecliptic. In the most extraordinary manner it may come and go. The planets all revolve round the Sun in the same direction, but a comet's path may be either direct or retrograde. Halley's Comet is retrograde.

In these days comets have lost all their terrors to the astronomer, because he knows something of their true dimensions. Though they bulk large in volume, yet the mass of the largest must be exceedingly small. The largest telescope fails to magnify the nucleus into a disc even when they approach to a minimum distance. Lexell's Comet of 1770 got entangled among the satellites of Jupiter without causing any inconvenience whatever to Jupiter's followers, and the same comet approached the Earth to within 1¼ million miles, yet it showed no disc and did not affect our planet in any way. Seeing that the mass of a comet is so small it is rather surprising and exceedingly interesting to find how wonderfully stable Halley's Comet has been in its ways.

Messrs. Cowell and Crommelin have shown that the inclination of this comet to the ecliptic in 1066 was 16° 5′, in 1607 17° 6′, in 1759 17° 36′ and in 1910 17° 47′, *i.e.*, in nearly a thousand years the inclination has only varied about one degree. Hind has traced the comet back to 11 B.C. and he finds most remarkable stability and regularity in its periodic visitation.

In the early stage, when it is far from the Sun, a comet appears round and nebulous, and apart from its motion among the stars it is not possible then to distinguish it from an ordinary nebula. I well remember, on the 28th February 1910, first catching sight of Halley's Comet. It was circular in shape and nebulous in appearance and there was no nucleus. It could only then be seen through the telescope. Up to March 7 it remained like this, and then it disappeared in the Sun's glare, and it was not until the 20th April that I again caught sight of it in the early morning. In the meantime it had changed in appearance. There was now a well-defined nucleus sharp and bright like a star. This was surrounded by a circular patch and produced into a tail and a bright star was shining through the tail. Speaking about stars inside the comet, on the 27th May, about 7-30 P.M., I noticed a star in the head of the comet only a short distance from the nucleus. For over 2 hours I watched that star. Gradually the nucleus drew nearer until about 9-20 (Standard Time) the star was so close that the two resembled a double star, closer than the components of Polaris and about as close as the components of the well-known double-star Castor, *i.e.*, 5″ apart. When at its nearest point to the nucleus I noticed a very slight diminution in the brightness of the star, but only at this point. Elsewhere the star shone out through the comet's tail and head undimmed in brightness.

Another important feature in connection with this comet was this. On the 19th May 1910 the comet passed between the Earth and the Sun. There was a transit. Now had the comet's nucleus been appreciable in magnitude, it would have been seen as a small point on the background of the Sun's disc. I remember watching most carefully. I also took a photograph of the Sun, but not the slightest speck was discernible and in no part of the world was the slightest trace of the comet seen by any observer.

That physical organ, the comet's tail, we must study a little more closely. Most comets, not all, have a tail at the glorious part of their career. Some have more than one. When No. 3 Comet of 1903 was photographed at Greenwich 9 tails appeared on the plate. Extraordinary changes sometimes take place in this appendage from night to night as a study of the photographs clearly show, *e.g.*, notice the *white spots* travelling along the tail. Probably a new tail is formed each night.

Not only does the tail undergo violent and sometimes disruptive changes but occasionally the comet as a whole suffers violence. Comet Moorhouse of 1908 was one of these. On the night of September 29 it rejoiced in a substantial normal appendage, but all through the night of the 30th violent changes were taking place. A photograph taken on the night of the 1st October revealed the astounding fact that the tail had been separated from the body. In the telescope it looked as if the comet had completely lost its tail, but a photograph shows that a slight connection still existed in the shape of slender streamers. On the 15th October a still more violent change occurred, the comet actually broke in two.

The stuff of which a comet's tail is composed must be in a most highly attenuated condition, otherwise such phenomena as we have been describing could not take place. What, then, can be the condition and composition of a comet so slight in mass and yet so expansive and which yet obeys so precisely the law of gravitation ?

Here I would digress a moment. I would point out the reason why Astronomy should be taken up seriously in this great land of India. We have a wide area, for many months of the year we have perfectly clear skies especially in that part of the year, November, December, January, when the astronomers of Northern Europe find Practical Astronomy almost out of the question. At present apart from a few Government observatories there are in this country very few private observatories that are well equipped and in active use. Take the case of Halley's Comet. Two years ago I went to England on furlough. There I met Mr. Hinks, of Cambridge, a keen and able astronomer and author of a capital book on Astronomy. I asked him about the comet and what they in England thought of it. " A miserable failure," he said. " It was scarcely visible at all. Most people never saw it once." How different here. To us it was a magnificent object. I myself observed it carefully on 32 different occasions. Thus for the cause of the science we should be up and doing that our work might supplement the work of astronomers in other countries.

For our knowledge of the composition of comets we are largely indebted to that grand old amateur astronomer Sir William Huggins, now, alas ! no longer with us. In his early days he hesitated between the microscope and telescope. Eventually he decided—and fortunately for Astronomy he did so—in favour of the latter instrument. He fitted up an observatory and for a time systematically observed the planets, but becoming dissatisfied with the routine character of the work he began to cast about for some fresh kind of research upon the heavenly bodies. It was just at this time that Kirchhoff's (1859) great discovery of the true nature and chemical constitution of the Sun by the interpretation of the Fraunofer lines was announced. Here was the very kind of work Huggins wanted. He determined to extend Kirchhoff's method of research to the other heavenly bodies. Then he devised a number of instruments for spectroscopic work ; he fitted up a laboratory and for many months was engaged in snapping the spectra of chemical elements. Armed with these he turned his spectroscope on the stars and brought to light the fact that stars are composed of the same elements that exist in the Sun and Earth. He next turned his attention to nebulæ and was the first to discover bright lines in the spectra indicating that they consist of incandescent gases of which H. gas is the most prominent. Incidentally a comet appeared and here again he made a great discovery. He found that there was a continuous spectrum crossed by dark lines. This resembled the solar spectrum and indicated that the comet shone, partly at any rate, with reflected light, but he saw more. He noticed a second spectrum consisting of 3 *bright bands*. This was a still more startling discovery. It proved that the comet had light of its own, that it was incandescent. Further research showed that these bands could be produced in the laboratory and were peculiar to compounds of carbon. A comparison of the carbon-banded spectra of the laboratory with those of the comet showed that they were identical. Thus the mystery was solved or partly solved, for the comet's spectrum is not even yet fully understood, but one thing is certain all research into the composition of comets goes to show that carbon in some form or other is found there in an incandescent state. If any one wishes to see a comet spectrum let him examine the lower part of a spirit lamp or carbon dioxide or monoxide in a vacuum tube with a small spectroscope.

With the knowledge we have now gained from the spectroscope, let us go back to the comet as it approaches the Sun from infinite depths of space. Carbon, we have learned, in some form or other constitutes the most important element in its composition. Carbon is a common element. It is an important constituent of the Sun and planets, and, as we shall see later, of meteorites. On this planet carbon occurs in combination with other elements as carbonates, etc. It also occurs as pure carbon, *e.g.*, diamond, graphite, both of which are found in the older geological rocks. An interesting property of carbon is that it has the power of dissolving or occluding gases such as ammonia. It is to some extent soluble in molten iron and it is also capable of being reduced to a very fine state of subdivision, *e.g.*, smoke. In the laboratory carbon itself is a reducing agent, but is itself reduced from its compounds by various agents and deep down in the Earth where the temperature is exceedingly high such reducing processes are going on. But to return to the comet, it comes along, exceedingly slowly at first. At this stage it may consist of one solid piece of stone, or of several, but its mass is not very great. Its temperature may be low, but it is now in the Sun's influence, its velocity increases and its temperature rises. As it approaches the Sun its temperature rises still higher. Violent chemical reactions begin to take place. Occluded gases are given off and become incandescent. Explosions due to expansions of gases and material owing to the increased temperature take place. The carbon compounds are reduced and the pure carbon fuses and vaporises. Exhalations of carbon and probably other elements are driven off in an extremely attenuated condition, but these come in contact with the radiation of the Sun, *radiant heat*, *light*, *etc.* The comet's radiations are overcome and driven back and so the tail is formed. To some extent the radiations from the nucleus extend sunward and thereby we get the corona of the comet.

Spectrum analysis shows that the tail shines largely, almost entirely, by reflected light. And here let us call to mind Tyndall's classic experiment in which incidentally he shows that light itself is invisible. He caused a powerful beam of light to pass through a box in which all the dust particles had settled, the path of the beam was invisible. Then he allowed the slightest trace of impurity or dust to enter the box and the path of the beam instantly became visible though to the eye not a trace of any dust could be seen. This principle has been made use of in the Ultra Microscope from which we expect so much. A concentrated beam of sunlight is passed through a liquid containing in suspension excessively minute particles of various substances and then examined by an ordinary microscope. In this way particles altogether beyond the power of any microscope are illumined and rendered visible.

May not a comet's tail be in such a condition? So excessively minute are the particles of carbon or other substances that unless they were illumined by the sunlight they would be absolutely invisible. So excessively minute are they, finer than the finest dust, that the cloud of them constituting the comet's tail has not the power to dim the light of a star shining through.

Perhaps the most striking discovery made in reference to comets is their connection with meteors. The chief credit for this goes to the famous Italian astronomer, Schiaparelli, of Milan, famous also for his discovery of the canals of Mars. He compared the orbit of the Perseid Meteors, *i.e.*, that shower of meteors that have their radiant point in the constellation Perseus and which appear in August, with that of Comet III, 1862. He found that comet and meteors moved in the same track.

Biela's Comet illustrates this connection also and at the same time provides evidence in other directions. It was discovered in 1772 and periodically it visited us. In 1846 it astonished the world by breaking up into two comets, and so long as they were visible they travelled together side by side. In 1852 the twain again appeared, but now they were farther apart, and this time they appeared only to bid us goodbye, for they never re-appeared in that form. In 1872 they were again due to appear, but in their place a substitute came in the form of a great shower of meteors, the Andromedas. On November 27, 1885, and 1892, we had showers with the same radiant point. Thus we have a swarm of meteors converted out of the disruption of a comet.

Perhaps the most interesting case of all is that of the Leonids, which so disappointed us in 1899. In 1799 there was a gorgeous display of meteors. In 1833 a still more brilliant shower. I have often heard my grandfather describe the swarm. On the evening of the shower he was sitting in his room when suddenly a friend rushed in, crying: "John, let us pray, the world is coming to an end, the stars are falling, look," and my grandfather went out. The stars were, indeed, falling in every direction, for the sky, from his description, was full of them.

In 1866 my father was an eye witness. He had been invited to a friend's house on the top of a hill. As he walked up the hillside late in the evening, being somewhat of an amateur astronomer, he examined the sky on his way. It was cloudy, but here and there were openings, and across the clear patches he saw meteors shooting across in a most startling manner.

I, myself, was an eye witness of the 1899 (November 14) shower. I sat up for two whole nights. On the first night I counted and charted about 80 meteors and on the second about 90. It was a sad disappointment, but I hope for a better display in 1933.

Professor Adams found the orbit of this particular shower, *viz.*, the Leonids was an ellipse and that its elements corresponded almost precisely to those of Tempel's Comet of 1866.

Thus we are led irresistibly to the conclusion that there is an intimate connection between comets and meteor swarms.

One thing we should not forget, a very small stone can become a meteor. We remember the guinea-and-feather experiment of our younger days. In a vacuum both fall with the same velocity. The ether of space offers no resistance. A milligram and a ton if started with the same velocity would travel together side by side. Probably in most cases the mass of the ordinary meteor is exceedingly small, but on reaching our atmosphere friction raises its temperature and it becomes incandescent and then is dissipated in the atmosphere. A small amount of matter is therefore capable of producing a fine shower of meteors, hence a comet, small though it be in mass, may be capable, on disruption, of producing a first-class shower of "shooting stars."

Finally, let us turn to the composition of meteorites. In the first place, it is well known that meteorites contain certain gases in solution as it were. Sometimes as much as six times their bulk. The occluded gases are such as Carbon di-oxide, Carbon mon-oxide, Hydrogen, Marsh gas and Nitrogen and the inflammable gases invariably preponderate. On one famous occasion a certain Professor lecturing in the Royal Institution lit up the room for a time with the gas from a meteorite. An examination of such incandescent gases with a spectroscope gives a spectrum similar to that of a comet.

Or take the composition of the meteorites themselves. Carbon is a common element. The specimen presented to this Astronomical Society is one of this type, rich in carbon. Other elements occur of course, such as Sodium and Iron, but these are not inconsistent with the theory that the composition of meteorites resembles the composition of comets.* Thus we are forced to the conclusion that comets and meteors are practically the same substances in different forms. They are similar in composition and they move in the same orbits. Comets are known to have disappeared and their places taken by meteors. Comets in one sense resemble nebulæ. Nebulæ are the stuff out of which suns are made, comets are the stuff out of which meteors are made.

We have come to the end of this lecture. To those who would know the purpose that comets serve in the economy of Nature we have no reply to-night; we can only direct them to the words of the inspired writer, "Oh, Lord, how manifold are all thy works, in wisdom hast thou made them all."

The Great Star Map

By A. B. Chatwood, B.Sc., F.R.A.S., A.M.I.C.E.

The title which I have chosen for this evening's lecture, "The Great Star Map," does not indicate very clearly my subject, which is the Astrographic Chart and Catalogue: the title is due to Professor Turner and I adopted it as I could think of none better.

Perhaps I cannot do better than at once give you some idea of the nature and magnitude of the work carried by my title.

It comprises a map produced entirely by photography showing stars down to the 14th magnitude, say 150,000,000 star images. This map will consist of 22,180 sheets, about 17 or 18 inches by 22 inches, a single copy would form a pile 33 feet high and weigh about 4,000 lbs. The second portion of the work is a catalogue of the positions and magnitudes of all stars down to the 11th magnitude determined from a second set of photographs and containing about 9 or 10 million star measures. This catalogue, in volumes about 12″ × 10″, would take up about 30 feet of shelf room and weight ⅔ ton.

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* Sodium and Iron, in particular, were conspicuous in the spectrum of Moorhouse's Comet.

This work could, of course, not be carried out by a single observatory, it has been divided into 19 sections which have been undertaken by different observatories representative of a dozen countries.

It cannot be supposed that the Governments of a dozen different countries would have allowed it to be undertaken and provided the necessary funds—perhaps 80 lacs of rupees—unless astronomers had been able to show that the work had a serious object and was likely to lead to results commensurate with its cost. Although valuable results have already been achieved the original object was simply to store up a mass of data which would enable future generations to make advances in astronomical knowledge based on more accurate and extensive data than are available to us.

It is interesting to trace the causes which led us to the undertaking :—

As you are aware, the earliest star maps were made for astrological purposes and, later, maps were required for the use of sailors. About 1674 it was suggested that the angular distance of the Moon from the brighter stars—"the method of lunar distances"—could be utilized by sailors for obtaining their longitude : Flamsteed pointed out that no sufficiently accurate charts or catalogues then existed. Charles II, then King of England, at once founded Greenwich Observatory to remedy the defect and appointed Flamsteed the first Astronomer Royal. Half a century later Bradley became Astronomer Royal, and, among many other achievements, laid the foundation of our present knowledge of the positions of the stars. At this time only the brightest stars were observed.

Later on when attention was called to the fact that one term of Bode's Series or Law, with which you are all familiar, had no planet to represent it, it was suggested that the term might be represented not by a single planet—which would certainly have been discovered—but by a number of smaller bodies. Search was made and in a comparatively short time four minor planets were discovered. Further search was for a long time fruitless, although now several hundreds have been catalogued.

The search for these small bodies resembling telescopically faint stars necessitated the use of charts showing not only the bright stars but also the faint ones. With such charts it was possible to detect a minor planet by its motion relatively to these faint stars.

The process of making such charts by plotting measures made in the telescope with a micrometer and filling in the fainter stars by estimation is familiar to you. The *method*, however, is not important to our subject but the *fact* that there was great need of accurate maps showing faint as well as bright stars. This led in the first place to the charting of the Zodiac—in or near which minor planets might be expected to be found—in Berlin and also by Chacornac in France whose work was continued by the brothers Henry.

The work we are considering would of course have been impossible had it not been for the improvements in photography which only took place between 1850 and 1880.

About 1850 or soon afterwards the Americans, Bond and Rutherford, had done some work in stellar photography with wet collodion plates, and in 1857 Bond wrote a letter, which is remarkable, to the Hon. Wm. Michell; in this letter he clearly forecasts that the sensitiveness of plates will be increased: that larger instruments will be constructed and erected under better climatic conditions and he pointed out the great accuracy of the photographic process. He concluded his letter by saying:

"There is nothing, then, so extravagant in predicting a future application of photography to stellar astronomy on a most magnificent scale."

These forecasts have all been justified by subsequent events. It is noteworthy that Rutherford found the accuracy of the photographs so great that he was unable to do them justice with any micrometer screw then obtainable; he therefore abandoned his astronomical work and devoted himself to the perfecting of the screw. It is probably to Rutherford's work in this direction that much of the development of modern tool-making and engineering is due.

In 1882 the gelatine plate, which is so greatly superior to the collodion plate in sensitiveness, was in common use; some amateurs at the Cape attempted to obtain photographs of the great comet of that year, which no doubt many of you remember, but were defeated by the fact that the image moved on the plate and so gave confused images: Sir David Gill, then Astronomer Royal at the Cape, hearing of this, invited them to come to the Observatory and strap their cameras to the equatorial telescope which was driven by clockwork to counteract the effect of the Earth's rotation. Some excellent results were obtained in this way.

A correspondence ensued between Sir David Gill and Admiral Mouchez, French Government Astronomer, which resulted in an invitation being issued to all the world's leading astronomers to attend a conference at Paris. This conference took place in 1887 and was attended by 56 astronomers representing 19 countries.

In the meantime Dr. Common in England had utilized photography in producing with his reflecting telescopes the excellent photographs of nebulæ which are so well known: and the Henry Brothers of Paris, who have already been mentioned as carrying on the charting begun by Chacornac, had with infinite skill and patience produced an object glass of 13½″ aperture specially suited to photography. As you are well aware, the ordinary visual object glass is adjusted to bring the yellow and green portions of the spectrum to the best focus, as this is the portion of the spectrum which is most active in vision; but the vision of the photographic plates, if one may be permitted the expression, is most acute for the blue and violet rays so that the curves of the usual crown-flint object glass intended for one purpose are not suitable for the other.

The conference of 1887 marks a distinct epoch in the history of astronomy as it originated what may be called "co-operative astronomy." I should like, if I may, to express here an opinion which I hold very strongly, and to express it with all the force I can: it is that astronomy, the science on which we are all so keen, has reached a stage when co-operative work is essential, and that the work of half a dozen astronomers, whether amateur or professional, working in co-operation is of far more value than the work of the same half-dozen working independently.

Many important decisions were arrived at at the conference of 1887; the first of course was that observatories all over the world should co-operate and that this co-operation should be used to produce a complete series of star charts and maps.

The next decision arrived at was that an object glass of the ordinary type, but specially corrected for photography should be used. Dr. Common was naturally in favour of reflector, but he did not fail to point out its disadvantages especially its fickle behaviour under unfavourable atmospheric conditions. Pickering, of America, advocated what has now come to be known as a doublet, a combination of four lenses exactly similar to a large photographic lens, and it is probable, I think, that if the excellent work done by this type of lens had then been available that it would have been adopted.

The object glass which was, however, adopted was one of the ordinary type corrected for photography with which the excellent work shown by the Henry Brothers had been done.

Another decision which has had far-reaching results was that of impressing a network of lines carefully ruled at right-angles and equally spaced on the photographic plate before development.

Although it was well known that the gelatine film was not subject to such distortion as would be noticeable in ordinary photography, it was yet looked on with suspicion and it was considered likely that it might suffer from distortion which would be noticeable in stellar photography. The impression of the carefully ruled network of line now known as a "reseau," a name which is also applied to the ruled silver on glass plate from which it is printed, would enable distortion to be easily detected.

This decision led to a result, due I believe to Professor Turner, without which I do not think that there could have been the slightest hope of ever carrying the work through. When it was found that the distortion of the film was negligible he suggested that it would be quicker and better to utilize the reseau lines as fiduciary marks from which to measure the position of the star images than to use a micrometer screw.

This has been accomplished by fitting a scale divided on a glass diaphragm in the common focus of the objective and eye piece of the measuring microscope. In practice this scale divides the space between two reseau lines into 100 parts and positions are estimated to $\frac{1}{10}$ of this, that is to say, $0''\cdot3$ of arc or approximately $\frac{1}{5000}$ part of an inch.

I pointed out earlier in my lecture that the original object with which this work was undertaken was the amassing of data for the use of future generations : but happily important and valuable results have been obtained during the course of the work.

It has been thought that our Sun was one of the stars of a cluster, and counts of stars on our plates has so strengthened this presumption that it may be considered as a definite result.

I show slides of two stellar clusters, you will notice a great concentration of stars towards the centre. Recent work by Mr. Plummer and others leads us to believe that if we were situated in the centre of one of these clusters and counted the stars of various magnitudes we should find that the ratio of the number of stars of any magnitude to that of one magnitude brighter would be about 2.

If now we make an assumption as to the distribution of stars in space, for example that stars are distributed uniformly through space and are intrinsically equally bright, the latter part of the assumption is not of course correct, so we will refer to it later.

If we take this hypothesis of uniform distribution we may, as you will see, for the sake of definiteness and without invalidity, assume the stars of different magnitudes to be uniformly distributed over the surfaces of spheres of different radii, the radii being determined by the convention as to magnitudes such radii would be starting from the 2nd magnitude

10 16 25 40 63 100 etc.

On this assumption the ratio of the number of stars of any magnitude to that of one magnitude brighter would be 4.

Considering now our assumption that all stars are intrinsically equally bright as erroneous : let us assume them to be of 2, 3, 4, or any number "n" degrees of brightness and we shall find that our ratio will be greater than 4 for the first "n" magnitudes and 4 for the remainder. And whatever reasonable assumption we make we cannot get a ratio smaller than *four*.

Counts of the number of stars of each magnitude from 2 to 6 on our photographic plates give us a ratio of about 3 which can be accounted for by the existence of a solar cluster containing about 740 stars and for which no other explanation has been up so far forthcoming.

Up to now we have considered only the brighter stars and have considered our solar cluster as limited; if we considered our clusters as extending indefinitely we should not account for the ratio which we find on our plates and we are bound to look further for an explanation of our discrepancy.

Professor Kapetyn has suggested, for quite other reasons that space is permeated by matter which absorbs light in very much the same manner as a fog but of course to a much smaller extent. Fog, as you know, absorbs blue rays much more readily than red rays, so that lights seen through a fog always look yellower or redder than they really are. Kapetyn has estimated the density of this matter pervading space as such that it will absorb one-half the luminosity of a star in a journey of 40,000 billion miles. That there must be matter in space is very reasonable as we see matter constantly driven off from the Sun's corona and from comets. Professor Newall devoted his Presidential Address to the Royal Astronomical Society in 1909 to this subject.

Counts of stars on our photographic plates give, as I said, a ratio of about 3 and also show that the more distant stars are more red in colour than those nearer to us. Also, although with certain limitations doubling the exposure of a photographic plate doubles the effect on the plate, yet it does not when we are photographing stars give us as many extra stars as it should if there were no-light absorption in space.

From these counts Professor Turner has estimated that the " fog in space " is such as to absorb one-half the luminosity of a star in 4,000 billion miles, an estimate of its density which while ten times as great as Kapetyn's is considering the difficulty of the subject in very good accordance.

We thus have as results of this work the existence of :—a solar cluster of about 740 stars—fog in space.

Another result not strictly of this work but of work arising out of it and out of the discovery of Eros in 1900 is the determination by Mr. A. R. Hinks from photographs taken in various parts of the world of the solar parallax. A determination which has given us our distance from the Sun with a probable error of less than 27,000 miles.

In some cases plates have had to be repeated for various reasons, and a comparison of these corresponding plates has shown that the work will lead to the determination of a large number of proper motions. Until 9 or 10 years ago it was assumed that these proper motions were entirely at random. Kapetyn, however, suggested that this was not so but that the stars were moving generally in two streams. This has been confirmed by Dyson, and Eddington has from examination of these plates recently shown that these two streams have fairly definite points of apparent convergence.

The plates intended for reproduction as star charts are exposed three times, the plate being displaced in such a way that the three exposures form a small equilatoral triangle. Mr. Baillaud found in one case, I believe also in others later on, that one of the images of a star did not at all resemble the other two: on investigating this—and every little discrepancy is well worth investigating—it was found that owing to the intervention of clouds one of the exposures had been made on one night and the other two on the next: he suspected the discrepancy to be due to the fact that this star was a short period variable, a suspicion which was afterwards confirmed.

I need not remind you of the discovery of Nova Geminorum by Mr. F. A. Bellamy at Oxford, a discovery which was also due to the investigation of a discrepancy in this work.

I have now given you a brief sketch of the magnitude of the complete undertaking, of the various causes which led up to it and of the results which it has already been responsible for; I will now conclude my lecture by giving you some idea of how the work is carried out and of the enormous amount of detail and figuring involved; by the help of the slides I shall now show and explain to you.

Slides of an astrographic telescope, and slides of a complete set of record sheets of one plate were then shown and explained by the lecturer.

Jupiter, the Giant Planet

BY THE REV. J. MITCHELL, M.A., F.R.A.S.

THE subject of my lecture to-night is Jupiter, the Giant Planet, and it is fitting that this lecture should be delivered on a Thursday (Jupiter's Day or বৃহস্পতিবার).

The name Jupiter is a most appropriate one. Mythologically, Jupiter was supreme among the gods. As Zeus, he was the earliest, the greatest and the most renowned deity in the Greek Pantheon. As Jupiter, he was also the chief deity of the Romans. In the Solar system he is supreme, for he is the largest in size among the planets. He is almost supreme in brightness, only Venus surpassing him in this respect. When Jupiter and Venus appear side by side in the heavens, *i.e.*, when they are near conjunction, they present a most brilliant spectacle. Such a spectacle I well remember witnessing in the evening sky in January 1892, about 22 years ago, and the impression it made on my mind will never be effaced.

During the greater part of last year Jupiter was a brilliant object in the southern sky, and its altitude being about 45° it was favourably situated for an observer in this latitude, but our friends in England were not so fortunate, for Jupiter's altitude being only 17° no serious telescopic work could be done. It was, therefore, hoped that all possessors of telescopes living in lower latitudes would make good use of their opportunity. Fortunately for our Society, early in July, the mounting of the 7″ Merz refractor, belonging to the Observatory of the Indian Association for the Cultivation of Science, was completed, and Mr. Raman, to whose energy that mounting is largely due, lost no time in turning it on Jupiter. I also, in Bankura, used my 5″ Cooke on the planet on almost every favourable night. Between us, for we (to use an astronomical expression) have been in conjunction during most of the year, we have made a number of useful observations and about 150 sketches, of which I shall make the fullest use during the course of this lecture.

The regular observing of Jupiter in this country from May to almost the end of the year, when the planet disappeared in the Sun's rays, has taught me one lesson, and I would impress this on all amateur astronomers in India ; the lesson is this : " Do not despise the hot weather, and still more the rains, for astronomical purposes." To tell you the truth, the finest definition I have obtained, and certainly the most perfect views, of Jupiter were in July. I had also splendid views of the planet in May and a few in June. The old adage " All is not gold that glitters " is true when applied to the sky. Most of the brilliant nights in November and December I found were almost useless. The definition was scarcely even good. Stars more often than not were bloated, blazing masses of light and colour, instead of being points with regular diffraction rings round them. It is true the definition during the last month improved, but I scarcely think finer views of any object in the sky could be obtained than those in the middle of the year.

And here I would point out that Jupiter is, *facile princeps*, the planet of the amateur with a small telescope. In these days photography has to a considerable extent displaced the eye observations of not only small instruments but telescopes of the largest aperture for a great many purposes. No telescope can now compete with the photographic plate in the mapping of stars, in the delineating of comets and nebulæ or in the mapping of spectra. Photography is now competing strongly with small telescopes for detailed work on both Sun and Moon, for to-day photographs of small areas of both Sun and Moon of surpassing beauty and clearness of detail are taken. But a good 3″ or 4″ can still reveal a little more detail on the Moon visually than any telescope can produce photographically. With the planets, however, the state of things is different. Photographs of Mars, Jupiter and Saturn are taken systematically, but they are small and the details are meagre and indistinct at the best. Here, then, there is scope for the amateur. Jupiter through a good 4″ or 5″ on a good night is a revelation. It is dangerous prophesying, but it seems to me that for many years to come the camera will have no chance with the telescope, used visually, on Jupiter.

Let us now look at the position of Jupiter in the Solar system. The Sun's family is divided into two classes of 4 each. The first 4, Mercury, Venus, Earth and Mars, are the small yet dense members, the other 4, Jupiter, Saturn, Uranus and Neptune, are the large giant yet light members of the family. Between these two groups we have the asteroids, numbering several hundreds and considered by some to be the remains of a fractured planet. The asteroids consist of a ring of tiny planets circling round the Sun in the same way as the Leonids, or ring of meteors, the difference being that meteors are very much smaller fragments, mere dust compared with the minor planets. Of the 2nd class, *i.e.*, the class of the giants, Jupiter stands head and almost shoulders above his brethren, and he might be looked upon as the guardian brother of the family, and indeed he does exercise a considerable influence over his relatives and outsiders too, for no celestial object can come within the range of his influence without being attracted very considerably in his direction. Especially is this the case with comets. I remember in my lecture on Comets, a year ago, in this Hall, referring to the action of Jupiter in delaying the coming of Halley's Comet in 1759. It was calculated that the comet was delayed 618 days by the two planets, Jupiter and Saturn, and of these 518 were due to Jupiter.

For many centuries, and even to-day the belief is held by many in this country, people have believed that Jupiter exerted an influence, sometimes for good, and sometimes for evil, over the destinies of mankind. There are few guardians to-day who would allow their children to attend school for the first time on any day but Thursday. For such a purpose বৃহস্পতিবার (Thursday) is the auspicious day. To most people in Bengal 21 hours of this day are auspicious, but the remaining 3 are just the reverse.

If a child be born when the planet is in Cancer, then happy is that child. He will be magnanimous, faithful, bashful, of sweet and affable conversation, honourable, religious, just• wise, prudent, grateful and virtuous. He will be indulgent to his wife and children and will revere old age. He will be a great reliever of the poor and will hate all sordid actions. Would that Jupiter could be nailed up permanently in that benign constellation ? But if the child be born when the planet happens to be in Capricornus woe comes to the unfortunate one. He will waste his patrimony and will be hypocritically religious. He will be tenacious and obstinate in maintaining false tenets in religion. Ignorance, carelessness, grossness and dulness will characterise him through life. He will abase himself in all companies and will stoop when there is no necessity. When we consider Jupiter's brightness we are not surprised that people credit him with such power, and when we consider its immense size we are not surprised that its influence upon other celestial orbs should be so great. Compared with our Earth its diameter is 10 times as great, while compared with the Sun its diameter is only $\frac{1}{10}$ that of the parent, so that it occupies, in point of size, or volume, a sort of mid-way position between the two. In round numbers we have 8,000 miles as the diameter of the Earth, 85,000 as that of Jupiter and 850,000 the diameter of the Sun.

Whilst Jupiter is immensely larger—1,300 times—in volume than the Earth, yet, being a light planet, its mass is considerably less, being in fact only 300 times that of the mass of the Earth. Its density, therefore, is about ¼ that of the Earth, *i.e.*, a little higher than that of water.

Thus proportionately the force of gravity on the surface of Jupiter will not be the same as on the surface of the Earth; it is in reality only 2½ times as great. From this we must conclude that inhabitants on Jupiter—if any exist—must be much less than those here. A graceful young lady of 10 stones would, if transported to Jupiter, be at once changed into a heavy weight of 25 stones. The inhabitants of the planet will therefore be somewhat Lilliputian in stature and weight. It would not do to build a tower or chimney of the ordinary diameter and 100 yards high on Jupiter, for it would be crushed by its own weight, so the size of the inhabitants as well as buildings will have to be inversely as the gravity.

Jupiter revolves round the Sun about once in 12 years at a distance of 482 million miles, but this does not matter very much to its inhabitants, for it is practically without seasons, the reason being that its axis of rotation is almost vertical to the plane of its orbit. What a monotonous state of things this produces it is scarcely possible to imagine.

How many of us realise what we owe to the fact that the axis of the Earth's revolution is inclined 23½° from the vertical to the plane of our orbit. Surely this is not accidental! Surely there is design in this! Suppose the axis were not inclined, that is were vertical, then all our days would be alike. There would be monotony everywhere, the temperature would vary with the latitude and the winds would blow every day with an irritating regularity. At the Poles the Sun would hang on the horizon eternally. Round and round he would appear to revolve once in 24 hours, never sinking below and never rising above the horizon. At the Equator he would rise due in the East, move vertically overhead and set dead in the West. Every day would be the same from the Poles to the Equator, the altitude of the Sun at noon would be the true latitude, the Sun always rising in the East and setting in the West. Suppose the angle made by the polar axis to the vertical were greater than 23½°, then the seasons would be accentuated. Tropical weather would characterise for a time the temperate regions in summer and polar weather would obtain in winter in the same latitudes. Jupiter is in the former position. Pity the poor inhabitants.

Let us now examine the planet through a good 4″ or 5″ Refractor (a good 3″ will show the main details). If we are fortunate to see the interesting side we shall notice certain definite markings, perhaps a black spot. Watch steadily this spot for ½ hour and you will notice that it has shifted from right to left (really from left to right, for the telescope inverts all objects like an ordinary camera). Look from time to time for another ½ hour; the spot has travelled still farther and all the other definite markings along with it. Keep up the watch for another hour and the spot will by the end of that period have almost disappeared round the edge of the disc. What has happened? The observation shows that Jupiter is revolving so rapidly on its axis that 2 hours is sufficient to cause any particular feature situated fairly centrally on the disc to disappear. Continued observations upon the same spot, especially if the exact time of transit across the central meridian be noted, through a few weeks and then divided by the number of revolutions will give most accurately the true rotation period of that spot and of the planet itself—if the spot is a stationary one. The time for one rotation turns out to be about 10 hours or to be more exact 9 hours 55 minutes 28 seconds, but, as we shall afterwards see, it is difficult to ascertain what is the true rotation period of the planet itself, as spots have different rotation periods.

Think of it, such a mass revolving once in 10 hours. Now the diameter of Jupiter at the Equator is 88,000 miles. A little calculation will reveal the striking fact that a spot on the Equator travels, in the course of its revolution, at the rate of 8 miles per second. It is rather a strange coincidence that the planet in its orbit round the Sun travels bodily at the same rate. Comparing the velocity of Jupiter at the Equator with that of some of the other planets, we find that Saturn's velocity is 6 miles per second, our Earth 15 miles per minute, and Mars 10½ miles per minute, while the Sun's velocity is 12 miles per second. What must inevitably be the result—a globe 88,000 in diameter revolving once in 10 hours? Think of the centrifugal force, *i.e.*, the tendency of the particles to fly off at a tangent and so to bulge out at the Equator.

Hence we shall not be surprised to find that the shape of Jupiter is not spherical. A glance through a good telescope will show at once that this is actually the case, for he presents a most noticeable flattened appearance at the Poles and if truly an oblate spheroid. Accurate measurements show that the equatorial diameter is 88,200 miles and the polas diameter 83,000.

From a spectacular point of view Saturn undoubtedly comes first, but Jupiter is a good second in the telescope. To the naked eye it is a striking object. Indeed, so bright is it that many observers can see it in broad daylight especially when in opposition. In the telescope it presents a large, clear, slightly oval disc which is crossed by a series of dark and light bands, some of which are distinctly ruddy in colour. Then there are 4 satellites easily visible, nay some of them have been seen by the naked eye when favourably situated and a powerful telescope will see them in the day time. I have myself seen them several times with my 5″ quite easily when the Sun has been well up in the sky. (By the way, it does not take a large telescope to see the brighter stars in the day time. I can see Polaris, a star of the second magnitude only, by day through my Transit instrument, and this has an aperture only 2⅜″ in diameter.) A more careful view of the planet reveals the fact that it is one particular belt that is most reddish in colour, and this is the *South Equatorial* and one of the most interesting of all the belts. I once saw this ruddiness to great advantage. As a young man I was greatly interested in Astronomy, and I would walk or ride any distance to see through a telescope. On one occasion, in July 1889, I went to Southport, a distance of 60 miles from my home—and 60 miles was considered a great distance in those days. There I remained for a fortnight purposely to look through the telescope—a 6″ Cooke Refractor—belonging to Mr. Joseph Baxendall, Meteorologist to the Corporation. For 13 days I remained and each night was cloudy, and the last night came, for on the following day I had to return, but I was repaid for all my trouble and expense. The night turned out clear and there was an occultation of Jupiter by the Moon that night—a somewhat rare occurrence—and the only one I have ever witnessed. The occultation took place in daylight about an hour before sunset. It was an exhilarating sight to see the Moon creep up nearer and nearer to the planet, first occulting the satellites one by one, then the planet itself, then the remaining satellites. But it was at the re-appearance of the planet with its train that what I want to describe took place. It was then dark and the stars and Jupiter shone out brightly. At last one satellite burst forth from the edge of the Moon's disc, then another, then Jupiter itself appeared slowly, sharp and beautifully defined. As soon as the planet was clear from the Moon I noticed a wonderful contrast. The Moon was silvery white, the Southern Equatorial Belt of Jupiter, especially, showed up with a marked deep red colour, but the other belts appeared slightly red also. I shall never forget the contrast and I shall never forget the glorious spectacle. Now it was often a puzzle to me why Jupiter did not look, if not red like Mars, at any rate slightly red, for its chief belt is ruddy, but it shines out almost as *white* as Sirius. The reason is now known. It is because its reflective power is very great, greater than that of any other planet, twice that of Mars and the Earth, and 12 times that of Venus. It reflects 62% of the total light it receives from the Sun. When it is remembered that newly fallen snow only reflects 78% we can understand how wonderfully great its reflective power is. Thus the reason why Jupiter does not show up slightly red is because the slight redness is altogether masked by the whiteness reflected from the white belts.

Perhaps the most striking feature on Jupiter as seen through a good telescope is the famous *Red Spot* which is to be found in the red Southern Equatorial Belt. It is an elliptical shaped spot of enormous dimensions, being some 24,000 miles long from East to West and some 7,000 miles broad from North to South. It has a curious history which we must refer to.

It was first discovered by Professor Pritchett, of Glasgow, Missouri, United States of America, in July 1878 as a pale pinkish oval spot. Next year, 1879, it began to attract attention owing to the intensification of its colour. It was then brick-red in appearance, sharp in outline and somewhat like an elongated hexagon. It was by far the most conspicuous object on the surface of the planet. After 3 years of brightness its colour began to fade and in 1882 and 1883 it had almost ceased to be visible. In 1885 it began to recover and then it showed up as a faint, pink oval ring with its centre occupied by a white cloud which in the following year so extended as to almost obliterate its outline. Gradually the white veil cleared away and in May 1891 it had recovered much of the intensity of colour which had rendered it so conspicuous an object in 1879. It remained a bright object throughout 1892 and then began to fade again and by 1897 it had become practically invisible. From this date to last year it has been a difficult object, for the most part was scarcely visible. During the last year Mr. Raman and I were fortunate in having the Red Spot visible again and our work has centred largely on this famous feature. We have noticed in the course of our observations two striking characteristics of the spot :

(1) Its influence (both attractive and repulsive) on its surroundings;

(2) Its westward drift.

So far back as 1879 when the Red Spot first became conspicuous, Barnard, the celebrated American Astronomer, called attention in the *English Mechanic* to the repulsive force exerted by the spot. The belts on the North and South sides of the ellipse were bulged out and there was a sea of light almost completely round it. Drawings taken in 1888 show the same feature though not in so marked a degree. During the past year we have found evidence that this repulsive force still exists. Invariably I have noticed that immediately round the spot there is a sort of white border and that the darkness of the belt shades off in the neighbourhood of the spot, but what is even more interesting, we have evidence which seems to show that the spot exerts now an attractive force. A black narrow elongated spot, which on the 1st August was some 17,000 miles to the West of the ellipse, drifted East until on the 3rd September it had actually collided with it, *i.e.*, it was attracted at the rate of 500 miles per day. That it was attracted, and not merely drifted, appears to be shown by the fact that when it reached the spot there it struck and gradually shortened in length and became fainter and fainter until by the end of the month (September) it had completely disappeared. It appears certain that the lesser spot was entirely swallowed up by the greater.

Then as regards the drifting East of the Red Spot itself, Lohse investigated this drift most exhaustively between the years 1878 and 1897, and he found that its rotation period was longer than the rest of the surface of the planet. Calculating backwards he found it had wandered over more than $\frac{2}{3}$ the circumference of the parallel in which it was situated. Our observations last year undoubtedly confirmed Lohse's conclusion as regards the drift generally, but we found its rate of progress backwards, that is East, to be even more rapid than he calculated. We have found its rotation period to be 9 hours 55 minutes 41 seconds, whereas the general rotation appears to be about 9 hours 55 minutes 28 seconds. What, then, can the surface conditions of Jupiter be like which allow an enormous area to drift slowly backwards in this strange manner that at one and the same time exerts a repulsive and an attractive force ?

Inside, but on the southern side of the dark South Equatorial Belt there runs a narrow bright band about $\frac{1}{2}$ way round the planet, known as the South Tropical Disturbance. This bright band comes stealing along like a snake, when the Red Spot is on the left of the disc, for the preceding end has often a snake-like appearance, sometimes pointed, sometimes rounded, and sometimes swollen out like the top of a walking stick. On the 20th October I noticed a dent in the knob-like end and this persisted for 10 days, gradually filled up and then disappeared. I have also noticed irregularities along the northern edge of this band. These changes and appearances have been seen also by Mr. Raman.

Immediately preceding the South Tropical Disturbance Mr. Raman and I, about the end of August, noticed a notch in the dark band between the Southern Tropical Disturbance and the South Tropical Zone. This kept its position and persisted until well into September, when it appeared no longer as a notch but as a long drawn out hollow which gradually filled up.

In the middle of May I noticed a curious notch in the same dark band but much further to the West. Bad weather in June and the early part of July prevented further observations. However, on the 26th July there was no trace of it, but on the 23rd August I noticed a curious swelling in the same belt and in about the same longitude. This swelling continued until September 9, when it changed into a kind of faint gap in the belt, lengthening slightly as the days passed by until by the 30th October it was fully twice as long as before. Calculations show that this gap rotates more slowly than the Great Spot, *viz.*, 9 hours 55 minutes 25 seconds, and as this corresponds with the general rotation period of the planet it follows that there is not much drift in connection with this feature.

We now come to the great Equatorial Zone. This is a most active area and differential movements are going on here right round the planet. The most striking feature is the fairly regular system of arches with their bases pointing North. This arrangement can be seen at any position of the planet's revolution. The pillars of the arches are generally vertical, but they are often tilted. Sometimes to the left and occasionally to the right ; sometimes two arches coalesce into one large arch though the middle base remains.

At the lower part of each pillar is invariably a black rectangular spot or base. These arches are a most striking feature and were visible every time the planet was observed.

But we have not yet finished with this great Equatorial Band. Up to the 23rd September the dark South Equatorial Belt and the bright Equatorial Zone were about equal in breadth, but the next day I noticed that the South Equatorial

Belt was widening. Mr. Raman noticed the same change. This widening went on until October 15, when the belt had widened to such an extent as to swallow up the entire southern half of the Equatorial Band. This was surely a most momentous change. It meant that this belt had increased in breadth, some 13,000 miles in 22 days or at the rate of 600 miles a day.

Both Mr. Raman and I have noticed other minor changes, too numerous to be mentioned here such as the sudden appearance of bright and dark spots persisting for a day or two and then disappearing.

Up to this point I have confined my attention to the southern portion of the planet, and it is a striking fact that most of the changes that are visible occur in the southern regions (of the planet). Only very occasionally are spots or changes in the arrangement of the belts or zones seen in the northern areas. I have seen both dark spots and white spots in the Northern Equatorial Belt, but these have been infrequent. From Mr. Raman's slides you will see that this has been his experience also. The dark belts and the bright zones retain their regular straight appearances and are rarely ever ruffled.

We must now pass on to the consideration of Jupiter's satellites. To the possessor of a good 4″ or even 3″, if it be of excellent quality, the satellites are a never failing source of interest. Examine them on a good night. Four satellites are easily seen. An ordinary opera glass will see them, but they may not be seen all together. Sometimes 2 are visible on one side the planet and 2 on the other, sometimes 3 on one side and only 1 on the other. Sometimes they are all on one side. Sometimes 3 are visible on one side, the other being eclipsed by passing into the planet's shadow or by passing behind the disc of the planet. Occasionally no satellite is visible being either all eclipsed or occulted. This is a rare occurrence. Very often the shadow of a satellite may be seen on the disc. This is always a beautiful spectacle. The shadow is round and inky black, but cases have been known where the shadow was oval near the edge. But an even more beautiful sight is the satellite itself on the disc, and this is a frequent occurrence, for the planes of the satellites correspond closely with the plane of the planet's orbit. You see the bright satellite approaching the edge of the planet; then it passes on to the disc, and strange to say it remains for some time almost as brilliant as before. Then its light begins to pale, but not until several minutes have elapsed does it become dull. Now it loses its light and becomes so faint that when it traverses a bright zone it is very difficult to follow its course across the disc. Then when it nears the edge it begins to brighten up again, and long before it reaches the edge it shines out with the same brilliant lustre it possessed before.

The reason for this brightening up at the edge must be that the planet at its edge is darker or rather duller in appearance than in its central regions, and this seems to suggest that here we are looking through a greater depth of atmosphere than on the centre of the disc. The Sun shows the same darkening at its edge, but not so the Moon which has but little atmosphere if any at all.

From time to time strange phenomena take place with reference to these satellites. On one occasion the planet occulted a certain satellite, but the satellite instead of disappearing instantaneously, as is the case when a star is occulted by the Moon, was some 45 seconds before it entirely disappeared, in fact during that period it was actually shining through the edge or limb of the planet. This extraordinary phenomenon was seen by Mr. Todd, of Adelaide (Government Astronomer for South Australia), and his Assistant; no doubt can possibly be entertained by any impartial person as to the credibility of this occurrence, for both Mr. Todd and his Assistant were most capable and reliable observers, and they used a first-class telescope, an 8″ Cooke Refractor, moreover on 4 separate occasions they witnessed the same occurrence.

This can only mean that the outer layer of the planet on those occasions must have been sufficiently gaseous and transparent for the satellite to shine through an immense depth of the planet's outer substance.

The more we study the planet the more overwhelming do the problems associated with it appear to become.

The satellites of Jupiter follow the rule of the planets, *i.e.*, the inner ones are less than the outer ones. Nos. I and II are each about 2,000 miles in diameter and III and IV are about 3,000, their periods of revolution round their primary ranging from 1¾ day to 16¾ days.

To an inhabitant on the Moon, our Earth in the sky will look a huge object, but what will Jupiter with his mighty bulk look like to a dweller on its nearest satellite. A little calculation shows that the planet will appear in the sky as a globe with a diameter about 40 times greater than that of the Full Moon. Think of that monstrous ball in the heavens.

In our schooldays we were taught that Jupiter had 4 moons, but knowledge has advanced since then. On the 9th September (at midnight) 1892, Barnard of the Lick Observatory (California), whilst carefully examining the neighbourhood of

Jupiter with the 36″ Refractor, detected "an exceedingly small star" close to the planet and which he at once suspected to be a new satellite, a suspicion he soon verified. It was the discovery of the year and created a great sensation in the astronomical world. We with our 3″ or 5″ or 7″ telescopes cannot hope to see this addition to Jupiter's family for it is but a child of the 13th magnitude and lies very close to its parent.

But this is not all. In 1904 a 6th satellite and in 1905 a 7th were discovered photographically at the Lick Observatory, and in February 1908 an 8th was discovered by the camera at Greenwich, and this latest addition is of special interest, because its motion round the primary proves to be retrograde. The latest (*i.e.*, the 9th) addition (Phoebe) to Saturn's system has a retrograde motion also. How the supporters of the Nebular hypothesis reconcile these retrograde motions with their pet theory I am waiting to hear.

To formulate a theory that will fit and accurately account for all the extraordinary phenomena seen on the surface of Jupiter will require a better theorist than your lecturer to night, and I have to confess that theorising has never been my forte, still speculating as to the condition, or some of the conditions of things on such a strange planet is such a fascinating occupation that I feel in some measure drawn to it, even though hitherto I have been quite a stranger to such pursuits.

I think we may take it for granted that some kind of atmosphere exists on the planet. Vogel and Huggins have shown that the spectrum of Jupiter cannot be explained except on the ground that an atmosphere exists, for there are absorption lines which in all probability owe their origin to the dense atmosphere that surrounds the planet. Then how can we explain the dusky edge of the planet except on the ground that it has an atmosphere.

In Text Books it is generally stated that Jupiter shines to some extent by its own inherent light. If this be so, how can we explain the total extinction of a satellite when it enters the shadow cast by the planet? So far as I know, no satellite has ever been known to be visible, however faintly, white in the shadow. Now if any light emanated from the planet surely some of the great modern telescopes would either reveal the satellite visually or it would make some slight impression on the sensitive plate. If the planet give out light of its own it must be very slight. But even though it be proved that Jupiter gives off but little light, this is no proof that its surface is of the same cold nature as that of our

Earth. It may resemble cooling lava, hot and viscid, but giving off practically no light. Indeed, there is much to show that this is probably Jupiter's surface condition, otherwise how shall we explain the strange differential movements that are taking place almost everywhere in the southern regions and to some slight extent in the northern areas also? Some of these changing features are sufficiently permanent to persist for years. The Red Spot has been observed systematically for 38 years, and the general finding is that its rotation period is greater than that of any other feature on the planet. Indeed, scarcely any two spots or areas have the same rotation period. This would seem to show that the surface which we see is of a liquid or viscous nature and that the great Red Spot is a kind of floating island continent of a still more viscous nature which lags behind slightly owing to the friction of the atmosphere. Difficulties there are of course, but other phenomena appear to point in the same direction. You will remember the black rectangular spot I referred to in the early part of the lecture. This was attracted by the Red Spot and eventually entirely absorbed into its own substance. The elliptical shape of the spot, too, is evidence of the same kind. The broadening of the great South Equatorial Belt can be partly explained by this theory and so can the notch that appeared in front of the South Tropical Disturbance, at first deep and narrow but later shallow and long drawn out. To explain the origin of the spots, white and black and red as well as notches, protuberances, arches and such like phenomena is not easy in this state of our limited knowledge of the planet. If we assume that the surface is in a more or less viscous condition we must also take it for granted that vulcanicity is rife, and in all probability on an enormous scale on the planet. There have been periods in the past on the Earth when there have been outpourings of volcanic matter on a stupendous scale, the lava so poured out has varied in colour. We have the basic lava-basalt, black as ink in places, we have the acid lavas, the trachytes and rhyolites light or grey in appearance. And then we must not forget the immense volumes of steam that always accompany each outpouring. Take one or two areas: the *Deccan* outpouring and the basaltic outflow covering the North of Ireland and West of Scotland. We can quite imagine a black spot could be found on Jupiter's surface when we remember what has taken place on our own planet. The notch preceding the South Tropical Disturbance might well be a huge outpouring partly in the South Tropical Belt and South Tropical Zone. And we see it as a notch only because the southern half is of the same colour as the South Tropical Zone.

The gap I referred to appeared at first as a kind of swelling, but afterwards the colours in the swelling and zones merged and we could only see it as a gap. But there are difficulties and I can at best only make a few suggestions.

And, after all, we must not be dogmatic for our knowledge of the planet is still meagre. But I think "we have seen sufficient to show us that the planet is not yet in a condition to sustain life such as this Earth sustains." It is evidently still in its infancy, but surely it is being prepared for some noble purpose. Can such a magnificent orb, with such a magnificent array of attendants circling round it, exist merely to reflect a feeble light to a few planets in this Solar system ? I cannot think this. I would prefer to think its Creator has designed it for a higher purpose. I prefer to apply to it the words of the great inspired seer who spoke: "For thus saith the Lord that created the heavens, God himself that formed the world and made it ; he hath established it, he created it not in vain, he formed it to be inhabited."

Saturn and His System

By C. V. Raman, M.A.

At the Town Hall on the evening of Friday the 12th March 1915, a lecture on Saturn, his system of rings and moons was delivered by Mr. C. V. Raman, M.A., under the auspices of the Astronomical Society of India. The Hon. Mr. W. A. Lee presided.

The lecturer said that Saturn was undoubtedly the most beautiful and most interesting of all planets, if not indeed of all celestial objects ; and the constitution of the planet and rings as disclosed by modern telescopic and spectroscopic research certainly added greatly to this interest. Saturn was known and his movements had been studied from the remotest antiquities and in common with the other planets he had been given a place in the Pantheon. The fact that had most impressed the ancients was the extreme slowness of his movement along the signs of the Zodiac. The lecturer explained that according to modern ideas, this apparent movement was due jointly to the movements of Saturn and the Earth round the Sun, and its smallness was due to the great length of the period of revolution of Saturn ; and also to his distance from the Sun being large compared with the diameter of the Earth's orbit. This slowness of Saturn's movement was remarked by the ancients and was given an astrological significance. The ancients had rightly placed Saturn at the extreme outer limit of the planetary system as then known to them. It was a matter of speculation whether the ancients were aware of the beautiful ring-system that circled the planets. Among the Assyrian tablets unearthed by Layard were some representations of the god Nisroch in which he was shown surrounded by a circular ring, and there were also other tablets which suggested that the Chaldeans had, at least in a crude way, observed the rings of Saturn. This did not seem inherently improbable as there was tangible evidence that the Assyrians knew the art of making glass and of shaping lenses, though perhaps only of an imperfect kind. The lecturer said that of late he had been making careful observations of Saturn through the seven-inch Merz equatorially mounted telescope belonging to the Science Association in Bow Bazar Street and was much struck with the extraordinary fineness of the detail that could be made out with the instruments. The lecturer explained from optical principles how it was that planetary detail far beyond the limit of resolution of a telescope as applicable in the case of multiple stars could be readily made out and appreciated.

The lecturer said that he had studied this question of the visibility of planetary detail by laboratory methods. It was essentially a case of obliteration of detail by the "diffraction" of light due to the finiteness of the aperature and of the wave-length of the light, and it appeared that a dark gap such as the Cassinis division in the ring-system of Saturn would continue to be visible to the eye long after a double or multiple star of equal separation would merge into one continuous spot of light. The lecturer said it was this that was the real explanation why visual observation of planets even through a small telescope showed a great deal more than a photograph of the planet secured even with the aid of the largest telescope.

The lecturer then gave an account of the various phenomena exhibited at different periods by the rings and satellites and explained how the shadow of the ball on the rings and of the rings on the ball, and the transparency of the innermost and outermost portions of the rings all contributed to the telescopic appearance of the planet. Photographs of the planet and of the spectrum of the ball and the rings had been taken at several observatories and the lecturer explained how these revealed the structure of the rings surrounding the planet as consisting of separate discrete particles of matter reflecting sunlight.

The Coming of Night

By Muriel A. E. Brown.

The long hot day comes to an end
And swiftly sinks the setting sun
Seeming in clearest ambience
Of green and gold, straight to descend
Upon the widely stretching plain,
Beyond the range of flat topped hills
Now purple in the glory
Of the glowing sunset stain,
High in the zenith I descry
A lonely star—yet pale and dim,
Serene and calm, it seems to swim
In blue grey ether, and to my eye
Appears what to the ear
Is the muezzin call to prayer
Floating o'er distant plain and hill
Soft and remote yet very clear.
Nature, attuned to prayer one feels
Lies hushed and still the colour gone
From out the west, and seeks to pause
Ere she her greatest splendours will reveal
My soul expectant throbs, and still
The Herald Planet shines more bright,
First one sweet star steals into vision,
Then another, and soon the Heavens fill
With one grand glittering train
Of burning and scintillating stars
Against a vault of blackest night
Above the silent plain.
Gazing up my spirit shrinks
And falters, trembling, at the sight
Of Majesty so glorious.
Those stars are suns—one scarcely thinks

The human brain can grasp or know
What such a definition means
And yet retain its hold on life
With all its petty influences low.
That high-way across the heavens
The Ecliptic Path I note
In which the planets find their road
To rise or set at even.
Now too the picture book unrolls
Of all the Constellations old
As they so slowly wheel and turn
Majestically round the Pole ;
Yon band of gently beaming light
Which sweeps across the sky
Must be a flight of spirits pure
Revealed more clear by sense than sight.
Near the Chabutra where I lie
A subtle fragrance fills the air,
Known on earth as Jessamine,
But surely starry petals dropped
By those sweet spirits as they fly
Along the gleaming Milky Way,
Whose fragrance is a message sent
Of life Divine with us to stay.

SUTNA,
15th November 1915.